Summary Report

Hydrologic Evaluation of the Big Wood and Silver Creek Watersheds

By

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PREFACE

Water and "Quality of Life" go hand in hand in Idaho. This condition is especially true in the Wood River Valley where the economic engines of recreational tourism and agriculture drive the connection between water, nature, and human existence even harder. In the early 1990s, a growing awareness of the critical connection between water and life quality prompted several key local organizations and individuals to initiate a discussion on how to acquire a better grasp of water resources. For varying reasons, from economics to ecology, everyone agreed upon the necessity of knowing more about the region's water resources. In short, there was a clear need for a systematic, scientific inventory of the Big Wood River and Silver Creek Valley's water resources.

In 1993, an extensive scientific project was initiated to better enable the citizens of Blaine County, Idaho to understand the water resources of the complex watershed in which they live. For a seven year period (1993-2000), The Nature Conservancy and a coalition of partners guided this study. The project's primary purpose was to inventory and evaluate the water resource system connecting the Wood River Valley and Silver Creek. This consortium of organizations---comprised of municipal and county governments, water and sewer districts, private companies and individuals, and non-profit organizations---contracted with scientists from the University of Idaho's Idaho Water Resources Research Institute to develop a model of the watershed basin. Now the data collection and analysis phases are completed, this *Summary Report* is designed to facilitate discussion by providing a non-technical overview pulling together previous investigations and distilling key findings into a single, non-technical document.

A primary goal of this *Report* is to synthesize and highlight the methods and findings of two technical reports known collectively as ***Phases I*** and ***II*** of the ***Hydrologic Evaluation of the Big Wood River and Silver Creek Watersheds***. While the focus of this *Summary Report* is upon ***Phases I & II***, this *Summary* also reaches out to incorporate pertinent findings of other investigations as well as provide some original perspectives, organization, and analysis. As a result, certain topics presented in this *Summary* are not always found *per se* in ***Phases I & II***.

Several steps have been taken to make this *Summary Report* "reader friendly." For example, for those unfamiliar with vocabulary of water science a ***Glossary*** is provided (Appendix 1). The reader is "notified" a certain technical term can be found in the *Glossary* by its appearance in bold and underlined (i.e. **aquifer**). Next, a separate and detailed "conceptual model" of the physical features of the Big Wood River Valley and its aquifer is included (Appendix 2). Third, a list of modern reference texts is given for those wishing to explore further the technical aspects of water resources (Appendix 3). Lastly, the "Conclusions" section of this *Summary Report* is presented with the non-technical reader in mind. More specifically, the final section attempts to address "frequently" asked questions about water resources in the region. Technical summaries, however, can be referenced in both the ***Hydrologic Evaluation of the Big Wood River and Silver Creek Watersheds, Phase I*** and ***Phase II*** as well as at the end of important sections on the water resources and computer scenarios in this *Summary Report.*

On a final note, it is important to establish a tone of caution at the very beginning of this document. Issues of growth, economic development, and water are inextricably woven together in the Wood River Valley and any interpretation or application of research findings must be accompanied by healthy dose of tentativeness. Hydrology is a developing physical science and not without limitations. Facts and numbers reported, for example, can often give the illusion of a greater accuracy than is truly the case. It is true water scientists were asked to quantify water resources as much as possible and report their findings. Reporting figures, however, such as "1,331,040" acre feet a year of precipitation or "0.00002" as a confined storage coefficient tend to indicate a level of exactitude which, frankly, does not exist. In an effort to reduce misinterpretation, aggregate statistics are given to the third significant digit, thus a figure such as 563,211 acre feet becomes 563,000 acre feet.

It is also very important to clarify the concept of "Reference Year." Many of the statistics and findings reported in this document are a function of measurements taken in 1993-94, reference year, or time period, used to collect field data necessary to calibrate the MODFLOW model. Thus many numbers reported in the graphs, tables and text are stated in terms of measurements taken during the 1993-94 reference year and may (or may not) be at variance with other information gathered by other sources for longer time spans. Does this mean the model is invalid? No, not in the relative sense, because the model seeks to establish relationship between physical properties. At the same time it can mean the findings reported are high (or low) compared to values which could be brought in from a longer time period. For this reason the reader is well advised to remember a theme that will be echoed in this document that findings and numbers should be accepted in a "relative" rather than an "absolute sense." Adopting this tentativeness allows the placement of greater confidence in statistical relationships than absolute magnitudes.

As with any report, certain individuals always make the task of writing easier. In this case, I wish to thank The Nature Conservancy's Paul Todd, Mike Stevens, Lou Lunte and Anne Dalton along with the University of Idaho's Dr. Roy Mink, Clarence Robison, and Peg Hammel. Jack Brown (Sun Valley Water & Sewer), and Kurt Nelson (USFS Service) also provided guidance about the appropriate level for the project and Dr. Earl Ralston, Bob Stollar, and Norm Colby for their professional and helpful peer reviews.

For making the overall project possible, The Nature Conservancy of Idaho extends deep appreciation to the cities of Bellevue, Hailey, Ketchum and Sun Valley as well as the administrations of Blaine and Lincoln Counties. In like fashion, TNC also wishes to thank Water Districts 45, 37 & 37M, Sun Valley Water & Sewer District, Loving Creek Ranch, and numerous other individuals who contributed to completion of this study.

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PART I

THE STUDY AS A PROCESS

This *Summary Report* is divided into three broad categories. Part I centers upon key aspects of a process developed by the researchers as they sought to examine the water resources of the Big Wood River and Silver Creek watersheds. Highlights of this "process" involve: (1) explaining the origin, purpose, and objectives of studies focussing upon the Big Wood River and Silver Creek watersheds; (2) clarifying study site boundaries; and (3) presenting the computer model developed to estimate ground water resources.

PROJECT HISTORY & OVERVIEW

Beginning in the early 1920s, water scientists first examined the water resources of the Big Wood River and Silver Creek **watersheds**. These early investigations were often technically complex and of little interest to people outside professional engineering circles. Generally speaking, earlier studies of the water resources of the Wood River Valley were narrow in scope and focussed upon specialized aspects rather than the overall water situation.[1] Over the years, however, new pressures have been brought along on the coat tails of increasing population, thus triggering widespread interest in obtaining a better understanding of the region's water resources.

The Driving Force: Population Dynamics in Blaine County

The headwaters of the Big Wood River and Silver Creek Watersheds are located in Blaine County, Idaho (Figure 1). As is generally the case in today's American West, Idaho is challenged by the social, economic, and environmental dislocations introduced by population growth. Idaho's current population of 1.1 million is sparse by any standard; only eight states have fewer. Rurality in Idaho is revealed by the 1996 Census which found a population density of only 14 persons per square mile compared to the population density of, say, New Jersey and its 1,076 persons per square mile. Yet despite its small, widely distributed population, Idaho is facing rapid and disproportionate

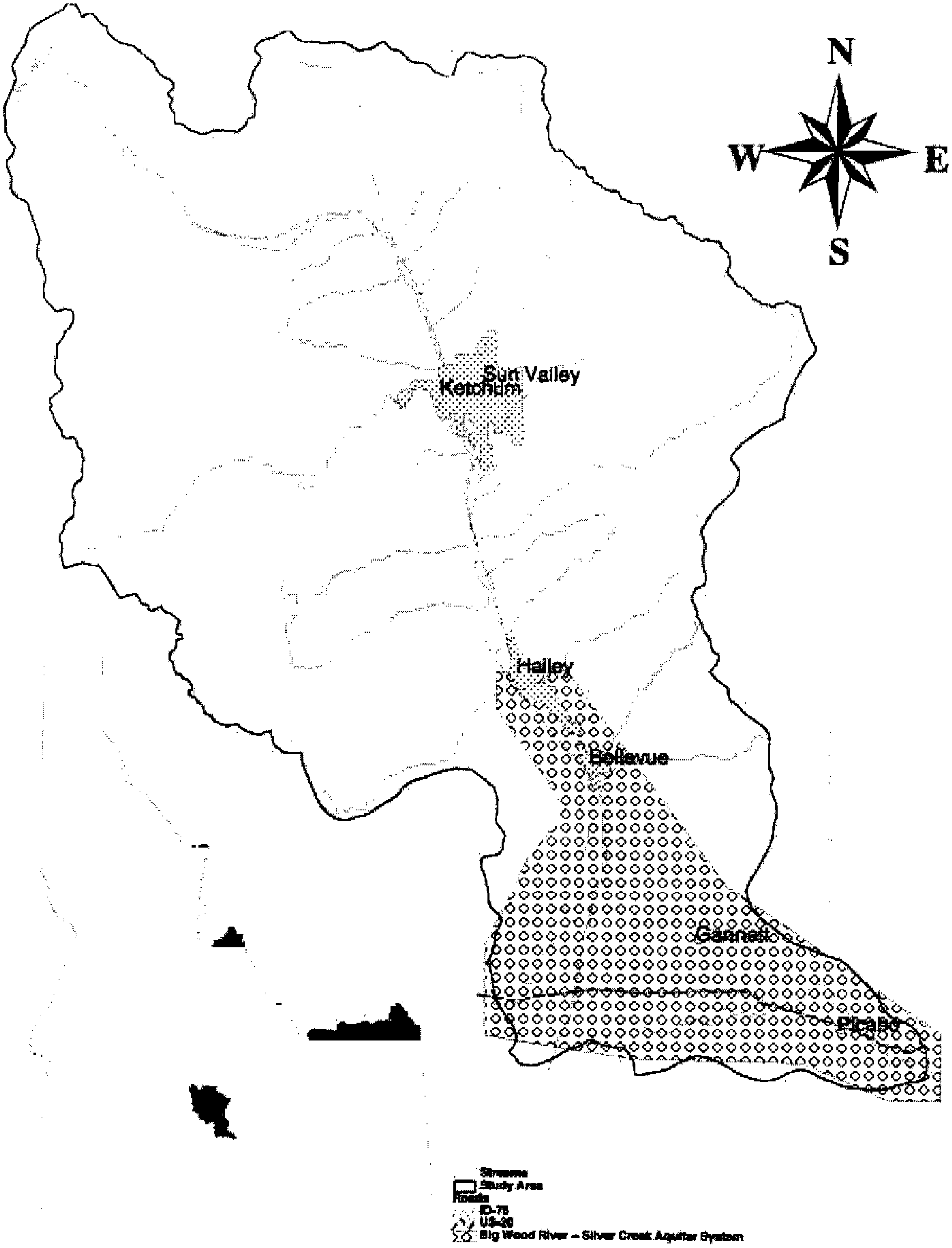


Figure 1. Big Wood River Watershed & MODFLOW Study Site

population growth. The population spurt between 1990 and 1996, for example, made Idaho the 3rd fastest growing state in the country.

What is true for the state is also true for Blaine County. Using U.S. Bureau of Census statistics, we can estimate a 67 percent increase in county population between 1980 and 1995 with today's population set at about 19,000.[2] Patterns of historical population growth indicate a future with more, not fewer people. Recent studies of Blaine County demographics place the "probable" number of additional residences, or dwelling units (DU), which could be added to the region around 15,000. In other words, the total number of persons living in Blaine County could increase over the next century to a ultimate buildout capacity ranging anywhere from 50,000 to 78,000 persons.

Thinking of Blaine County's current population as "spread out" over its 1.6 million acres (2600 square miles) can be misleading since much of the county is either uninhabitable or owned by government agencies disallowing private development on public lands. Geographic limitations are especially noticeable where most of the population boom is taking place: the Wood River Valley. Here, virtually all growth has been compressed into a narrow corridor less than a few wide and 25 miles long. The intensity of this development has stimulated a concern for what many fear is an increasingly degraded environmental quality. A heightened sensitivity to the watershed fragility has triggered substantial discussion concerning the future impact of population growth upon the Big Wood River and Silver Creek regions. As with most western communities, the usual topics have emerged such as access to recreation sites, hillside development, traffic congestion, fish and wildlife habitat, changing land use patterns, light pollution, air quality, stable economies, schools and affordable housing. In addition to this list, and always at the top, is that constant anxiety of all semi-arid western communities: water.

Early Project History: The Nature Conservancy and Its Partners

Realizing the critical connection between water and the quality of life prompted several key local organizations and individuals in the early 1990s to seek a better scientific grasp of water resources. Stimulated for various reasons---from economics to ecology---a widespread call surfaced to make a systematic, scientific inventory of the Big Wood River and Silver Creek watersheds.

Several previous studies had already examined selected aspects of the Wood River Valley's surface and ground water elements (Castelin and Chapman, 1972; Castelin and Winner, 1975; Grover and Brockway, 1978; and Luttrell and Brockway, 1982, 1984).[3] By and large, these studies explored only selected elements of water issues while making no attempt to integrate their findings into a larger, comprehensive assessment of the region's water resources.

The Nature Conservancy (TNC), as steward of the Silver Creek Preserve, was especially interested in the future sustainability of the spring flows comprising the headwaters of Silver Creek (Figure 2). Stakes were raised in the late 1980s when warm and dry conditions settled over the entire West. During this period between 1987 to 1992---and reoccurring in 1994---the Big Wood River and Silver Creek experienced their second lowest flows since record keeping began in the 1920s. As a result, TNC initiated a monitoring program to gauge several measures of water quality in Silver Creek (i.e. temperature, dissolved oxygen, flow volume).[4] On June 23, 1992 low flows coupled with warm temperatures reduced necessary dissolved oxygen levels to the point over 50 large trout died in Silver Creek. This event convinced Conservancy managers it was time to look beyond measuring water quality and to also study water quantity.

With TNC spearheading the process, a group of agricultural irrigators joined other interested individuals, organizations, and public agencies to examine the nature of the water resources system.[5] This "Steering Committee," undertook the initial oversight of a comprehensive scientific study probing the connection between Silver Creek and the surface and sub-surface waters of the Wood River Valley. In April of 1993, TNC contracted the University of Idaho's, Idaho Water Resources Research Institute (IWRRI) to initiate the first step of what would become a two-phase study. The first phase was supposed to review and integrate previous studies as well as collect new data followed by a second phase incorporating this new information into a computer **model** as well as extending selected aspects of the investigation to the upper Wood River Valley.

Phase I, funded primarily by TNC, was led by IWRRI's Drs. Charles Brockway and Akram Kahlown. For 17 months they gathered information ultimately published as ***Hydrologic Evaluation of the Big Wood River and Silver Creek Watersheds: Phase I.***

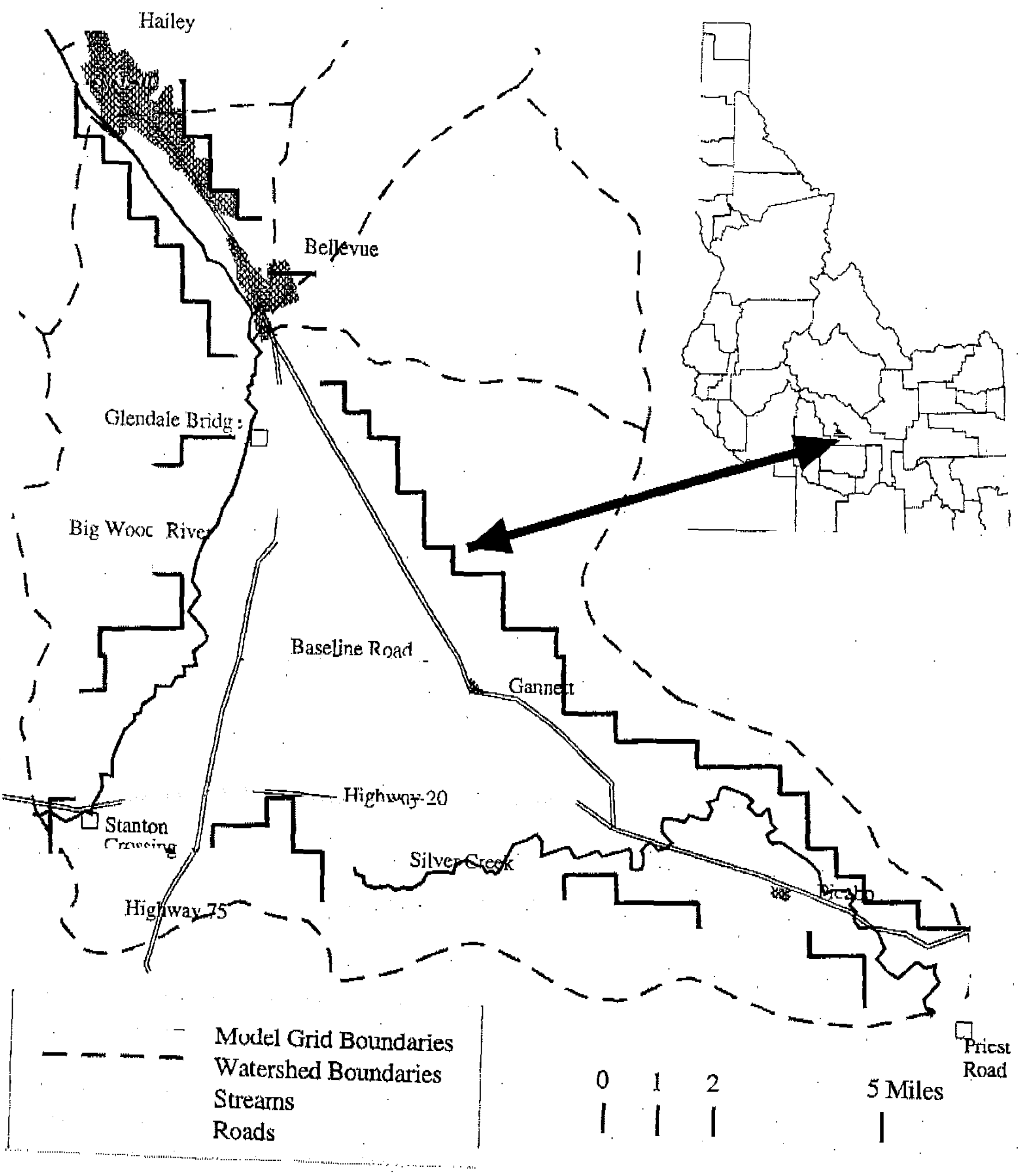


Figure 2. Location of Bellevue Triangle and Silver Creek

This work, and its accompanying ***Executive Summary,*** was completed in November of 1994.[6] As ***Phase I*** was being completed, IWRRI submitted another proposal for ***Phase II*** in July of 1994. The Nature Conservancy approved a second phase and work began in September of 1995 with a completion date set for February of 1997. Difficulties in model calibration augmented by changes in IWRRI research staff contributed to delays and the final report was not finished until March 2000. For purposes of clarity in this *Summary Report*, whenever both the ***Phase I*** and ***Phase II*** studies are referred to collectively, they will be designated as ***Reports.***

RESEARCH OBJECTIVES: *PHASE I & PHASE II*

The Nature Conservancy became the leader in sponsoring ***Reports*** and it was TNC's primary concern to explore the situation facing Silver Creek. Of course, a focus on Silver Creek does not mean it can be studied in a vacuum because surface and ground waters of the Big Wood River watershed are inextricably connected with Silver Creek. For analytic reasons, Silver Creek became what scientists call the "dependent variable." In other words, this term refers to the target of the study and the water resources system of Silver Creek can be said to "depend" upon other factors. In similar fashion, the "independent" variables are those factors which determine spring flows in Silver Creek such as amount and type of irrigated agriculture, surface diversions from the Big Wood River ground water pumpage, precipitation, and population growth.

Phase I - Objectives

The stated purpose of ***Phase I*** was "...to develop a basic understanding of the hydrologic interactions of water sources, stream-aquifer systems, and effects of natural system changes and man-induced land use changes." More specifically, the collaborative agreement between TNC and the University of Idaho specified five objectives:[7]

1. collect, review, and document the hydrological, geological, meteorological and land use data of previous studies;
2. establish surface and ground water monitoring networks and collect field hydrological, meteorological, and land use data for subsequent development of a predictive 3-D ground water model of the basin;
3. develop a tentative current conditions water budget for the aquifer system of the Big Wood River-Silver Creek area;
4. make a provisional selection of a ground water flow model including necessary subroutines and structure the collected data in a compatible format for entering into the model;
5. complete a final report summarizing results.

In order to achieve these objectives, researchers began in April of 1993 to collect the data necessary to update and fill-in the gaps of earlier efforts.[8]

Phase II - Objectives

Phase II differs from ***Phase I*** in one significant way. The primary objective of ***Phase II*** was to develop a ground water flow model using information collected in ***Phase I***. This model, originally developed by the United States Geologic Survey (USGS), is named **MODFLOW** and is a computerized tool visualizing the study area in three dimensions. Once developed, MODFLOW is capable of giving projections to questions submitted to it by different scenarios. In short, the model tries to project reactions to changes in either climatic or human conditions. ***Phase II*** was required to address ten specific objectives:[9]

1. procure the three dimensional MODFLOW model from USGS;
2. develop the model for the Big Wood River-Silver Creek aquifer;
3. simulate responses to the Big Wood River-Silver Creek aquifer due to changes in climatic and/or human factors;
4. predict future water supplies based on different land use scenarios;
5. quantify the annual recharge of the Big Wood River-Silver Creek aquifer;
6. estimate water withdrawn from the Big Wood-Silver Creek watershed south of the Sawtooth National Recreation Area;
7. estimate underflow leaving the study site's aquifer system;
8. review existing data and procure additional information on the area from Hailey to the Sun Valley locale;
9. analyze water requirements associated with various land uses;
10. estimate the water resources and evaluate the impact of future development on the water resources of the Hailey to Sun Valley locale.

THE STUDY SITE: Its Nested Nature

The "Preface" warned there would be times when this *Summary Report* would introduce a slightly difference organization or perspective from ***Reports***. One such alteration revolves around the use of the words "watershed" and "study site." In ***Reports***, the words "watershed" or "study site" can refer to any one of three different levels of analysis. The most comprehensive "study site" is the entire watershed of the Big Wood River, encompassing the mountains and valleys forming its headwaters. Nested within this comprehensive watershed is a second level of study site: the Wood River Valley. Of course, the Wood River Valley is, itself, further subdivided into two smaller study sites: the "upper" and "lower" valleys. Descending down to the final rung of the ladder, we find a third usage of the term study site, one introducing the artificial boundaries defined by the researchers for the MODFLOW model.

Even though the study sites are, for analytical purposes, discussed as if discrete entities, they are connected by a complex web of surface and ground water relationships. In a word, the study sites are nested one within each other. The following description outlines key geographic and physical features of each level and their key hydrologic features are explained in Part II (see Appendix 2).

Watershed 1 – The Big Wood River

At the most encompassing level is the watershed of the Big Wood River, an 881 square miles area defined by the ridgelines of the Pioneer, Boulder, and Smoky Mountains.[10] IWRRI researchers divided the Big Wood River watershed into 28 subwatersheds[11] (Figure 3). Average annual precipitation falling within the Big Wood River watershed is approximated at 1,330,000 **acre feet** per year (af/y) and 70 percent of this amount (946,000 af/y) is lost to **evapotranspiration.**[12] **Yield** is thought to be between 330,000 af/y to 345,000 af/y. Computation of "yield" is complicated and a variety of methods for making such a determination are found in hydrology (please see Glossary and Endnote).[13]

Watershed 2 – The Wood River Valley: Upper & Lower

The centerpiece of the Big Wood River watershed is the Wood River Valley itself. Trending in a north-south direction the valley begins in the north as a narrow slot less than 1/8th mile across at Galena Summit. As one travels southward, the valley floor declines in elevation from close to 9,000 feet above sea level to less than 5,000 feet. Thus the valley drops at an average rate of 0.008 feet for each foot (30 feet per mile) while it also widens slowly along a 50-mile path to its terminus at the Clay Bank, Timmerman, and Picabo Hills. By the time the valley is transected by Idaho State Highway 20 it is close to 15 miles wide. Using the location of Hailey as a mid-point of the Wood River Valley, average annual records indicate 16.5 inches of precipitation falling mostly between November and March. Mean annual temperatures at Hailey vary from 20° in January to 67° in July (see Appendix 2 for detailed discussion).

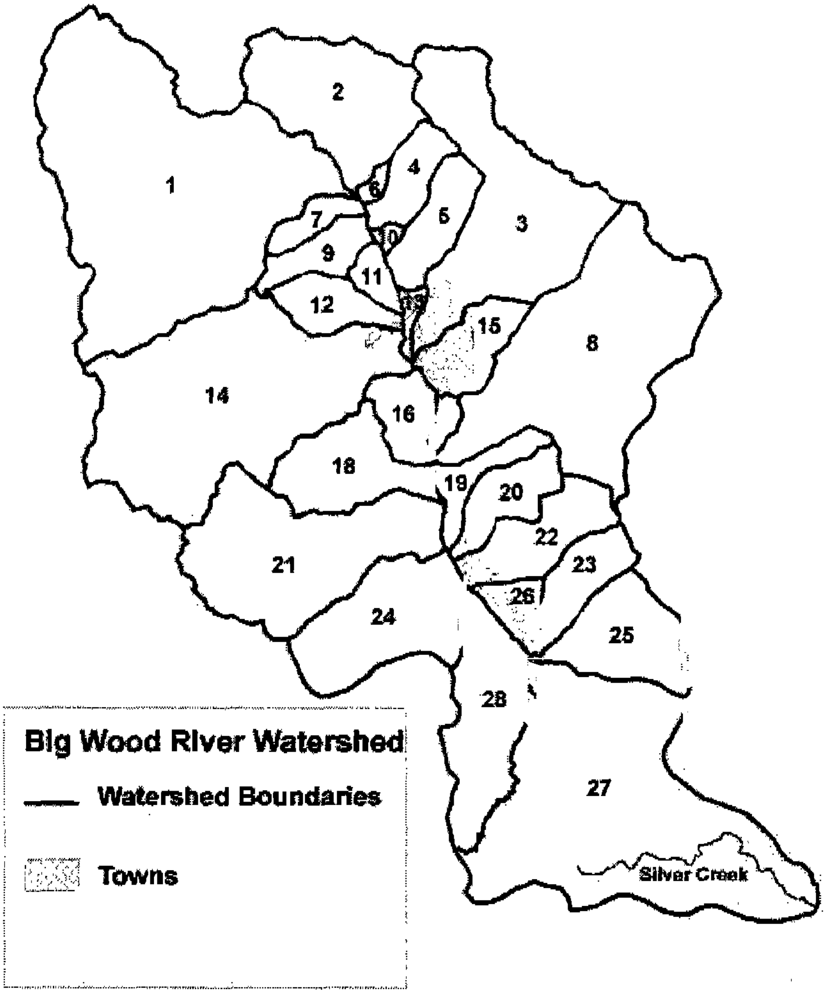


Figure 3. Big Wood River Watershed & Subwatersheds

Upper Wood River Valley – The upper Wood River Valley is nested within the Wood River Valley and is considered by this study and folk wisdom to be the region from Hailey northward. A commonly used point of reference separating the upper from the lower Wood River Valley is the USGS gauging station in Hailey near the confluence of Croy Creek and the Big Wood River. Ringed by mountain peaks as high as 10,000 feet, the Upper Valley watershed is approximately 626 square miles and contains the urban centers of Ketchum, Sun Valley as well as sub-divisions built in the un-incorporated county north of Hailey. For purposes of analysis, ***Reports*** considers the northern half of Hailey to be within the Upper Valley and the southern half in the Lower Valley.

Elevations above sea level average about 7,620 feet and temperatures, on the whole, are 5° F cooler than temperatures in Hailey. Precipitation is thought to be 1,110,000 af/y with an associated water yield of about 394,000 af/y depending upon estimation adopted. Vegetation in the Upper Valley is divided between 45 per cent forest land and 55 percent brush or grass.

One frequent concern for the Upper Valley centers upon growth and its associated economic and environmental ramifications. Human presence in the Upper Valley has existed for some time beginning with Native American populations and spurred again by immigration in the 19th century. Mining, ranching and irrigated agriculture in the last century helped create the Upper Valley municipalities where today 80 percent of Blaine County's population is compressed into the communities of Ketchum, Sun Valley and Hailey.

Lower Wood River Valley – The Lower Valley watershed is approximately 255 square miles and contains within it the geographic area known as the "Bellevue Triangle." In this *Summary* and also in ***Reports***, Hailey is designated as the apex of the triangle although earlier studies used Bellevue. From Hailey, one leg of the triangle runs southeast to Picabo and the other leg southwest to Stanton Crossing (Figure 2). Elevations in the Lower Valley range from 5,300 feet above sea level at Hailey to 4,800 feet and 4,750 feet at Stanton Crossing and Picabo respectively. Despite being characterized as a semi-arid, high desert climate, this region remains Blaine County's prime agricultural land.

Variability is precipitation is considerable within the Lower Valley. Records kept since the late 1950s show annual highs , for example, in 1969 and 1983 of 20 inches with lows of 8 inches or less in 1966 and 1992. ***Phase I*** estimates average annual precipitation between 1959 to 1993 to be about 13 inches.[14] In terms of volume, the Lower Valley receives approximately an average of 219,000 af, compared to the Upper Valley's 1.11 million acre feet.[15] Lower Valley yield is placed at 343,000 af with the same contingencies as pointed out above (and in Endnote 13). Due to Lower Valley aridity, about 87 percent of the 34,000 acres under cultivation are irrigated with either surface water from the Big Wood River or ground water from wells. Current croppage is a mixture mostly of pasture, barley and alfalfa, while potatoes, wheat, oats and canola comprise less than 7 percent of the remainder.[16]

The Silver Creek Preserve - Located within the Lower Valley's triangular region is, of course, the Silver Creek Preserve itself. This world class trout fly fishing stream and its surrounding wildlife preserve receives over 10,000 visitors a year contributing an estimated $2 million annually to the local economy.[17] Silver Creek Preserve encompasses the heart of a high-desert cold spring ecosystem comprised of 882 acres along 7 miles of Silver Creek and its tributary spring fed streams. Beyond the Preserve's boundaries are 20 conservation easements totaling another 8,000 acres and 25 miles of stream.

Land protection work initiated by TNC over the past decade has improved dramatically the quality of water and riparian habitat. Although Silver Creek is known primarily for its fishery, it also sustains many rare plants and animals. The stream's relatively steady flow, nurturing temperatures for fish (40° to 60° F), low stream gradient (≤ 1 percent), alkaline chemistry (pH 8 to 9), and high mineral content all contribute to a unique cold stream biology.

The springs feeding Silver Creek are the primary source of concern for its managers. Since the stream is entirely dependent upon its feeder springs, an objective of ***Reports*** was to assess the impact of changes taking place in the recharge zone of Silver Creek's springs; an aspect discussed in detail in Part II.

Watershed 3 – The MODFLOW Study Site

The level of third study site level is often the most difficult to understand. Associated with this difficulty is the fact that this level of study site does not actually exist in a physical sense, its boundaries are not mountains or streams. Moreover, researchers create an imaginary study site within the computer to help them understand a ground water system. This process is described in the following section, but for now suffice it to say the MODFLOW study site represents a 90 square mile area whose reference year precipitation was 51,300 acre feet and yield was 120,000 acre feet.[18]

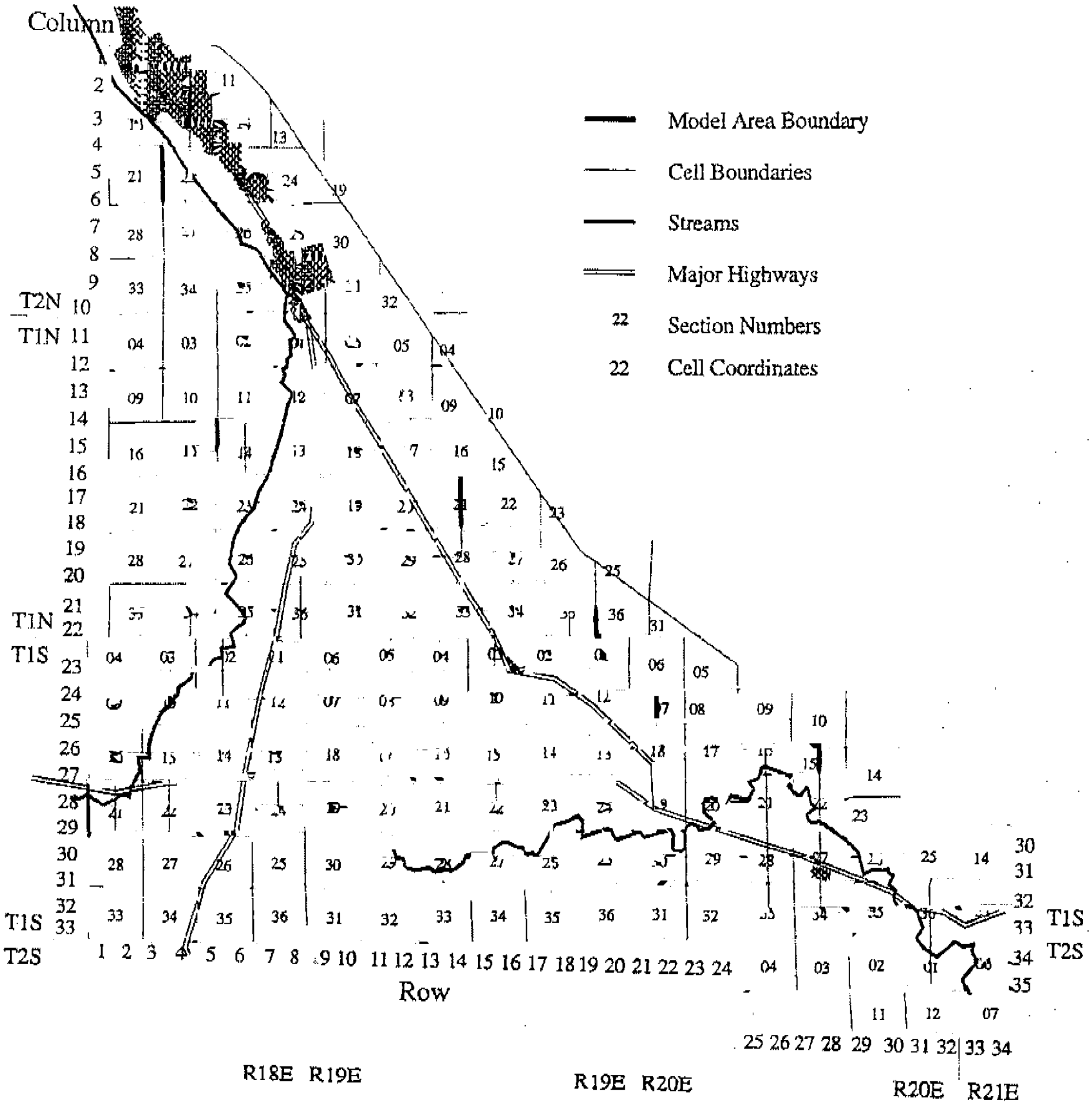


Figure 4. MODFLOW Ground Water Model Grid and Coordinates

THE MODFLOW MODEL: Description

Today, MODFLOW is a widely used application for simulating ground water flow and its popularity is attributed to ease of use and broad application.[19] The process of examining a ground water resources system using MODFLOW begins with the creation of what is known as a "model" of the target area. This conceptual model is a vision of the boundaries, physical characteristics, and relationships which define the aquifer and connect it to its surrounding geography and geology (the reader is strongly urged to see

Appendix 2). Once this phase is completed the researchers face the next task of converting the conceptual model into a machine readable format or "numerical" model. It is at this point where MODFLOW enters the picture because it is a scientific tool developed by two USGS scientists, McDonald and Harbaugh, in the early 1980s to help in this transition. In short, MODFLOW is a computer program which takes numerical information and tries to reconstruct the target area and its physical properties.

The MODFLOW study site is a grid comprised of 35 rows and 34 columns for a total of 357 cells superimposed over 90 square miles in the Bellevue Triangle; each cell represents a ½ mile by ½ mile (160 acre) area. Figure 4 illustrates the grid location and gives coordinates in two dimensions (rows and columns) which coincide with the traditional Public Land Survey designations of Section, Township and Range. The final MODFLOW model is in three dimensions since it also takes aquifer depth into account. The depth component, depicting subsurface layers, is set by the researcher's judgment.

Technically speaking, the model rests upon **Darcy's Law**, a scientific principle describing the rate at which a fluid moves through a porous medium. Darcy's Law permits MODFLOW to derive relationships between aquifer characteristics using measurements taken in the field.[20] Thus once the model's boundaries are set the analyst introduces data collected from other studies or information obtained during the reference year (again in this instance the 1993-94 period). Information typically useful would be changes data on water tables, well location, river seepage, underflow, spring discharge flow, irrigation diversion, precipitation and evapotranspiration. The incremental incorporation of this information into the computer model allows it to make generalizations about aquifer properties. In lay terms, these "properties" can inform the hydrologist about ground water direction and velocity, its volume, and how much water is retained with the aquifer. To the water scientist these features are known respectively as **hydraulic conductivity, transmissivity** and **storativity**.

A crucial phase of the modeling process hinges upon "calibration." Essentially, calibration means fine tuning the model until it renders answers acceptable to expectations of trained scientists. Once calibrated the model can be extended to evaluate other situations. Thus if analysts wished to know what conditions were like before human presence, a scenario could be constructed by removing the influence of wells, replacing cropland with natural vegetation, and so on. It is this feature of MODFLOW which allows the model to address the "what if" questions introduced as scenarios. What will happen to Silver Creek if, for example, pumping is halted in selected wells north of the Preserve? Or perhaps, what will happen to Silver Creek if homes replace farms in its recharge zone? Or, what will happen to Silver Creek if waste water flows from Hailey and Bellevue or excess flows from the Big Wood River are spread into recharge pits? A well-constructed model becomes a powerful tool not only for hydrologists but also for land managers, farmers, sportsmen, and other citizens to evaluate the tradeoffs of proposed actions.

The *Preface* introduced the importance of understanding the concept of "Reference Year," and it worthwhile to repeat this message. MODFLOW's reference year for calibration was from April 1993 to April 1994. Thus many statistics reported in this *Summary Report* are stated in terms numbers acquired during the reference year and may (or may not) be at variance with information gathered over a longer period of time and presented as average annual statistics. For example, examing the "Period of Record" (POR) for flows of the Big Wood River at Hailey will indicate average annual flows approximately 20 percent lower than the flows which occurred during the reference year. Does this mean the model is "off" by 20 percent? No, not in the relative sense, the condition of the relationship between variables when all fluctuate proportionately. On the other hand, the statement of a specific term's value could be "off" in an absolute sense by over or under estimating a term's long range value. In such a case, the 1916-94 records for Big Wood River at Hailey indicate average annual flows of 286,000 af/y while the reference year's were closer to 350,000 af/y. It is crucial to remember this distinction when reviewing hydrologic concepts as yield, budget, and the scenarios.

PART II

THE STUDY AS PRODUCT

Part I examined the processes and objectives of ***Reports***, Part II now turns to the "products" of these investigations by addressing three broad categories: (1) water resources of the upper and lower Wood River Valley; (2) water budgets of the Big Wood River watershed, upper/lower valleys and the MODFLOW study site; and (3) scenario outcomes. Again it should be noted most of the water values specified drawn from the 1993-94 reference year data.

WATER RESOURCES OF THE UPPER VALLEY

While ***Phase I*** did not examine the water resources of the Upper Valley, ***Phase II*** extended its scope to include this region.[21] Earlier, Figure 3 presented the northern 21 subwatersheds comprising the Upper Valley. These subwatersheds drain 626 square miles where an estimated 1.1 million acre feet of precipitation falls each year as rain or snow. Much of this water is withdrawn by evaporation from lakes and streams and the transpiration of plants and animals (699,000 af) as well as landscaping and agriculture (17,000 af). As stated earlier, Upper Valley yield for the reference year is approximated to be between 390,000 to 395,000 af/y; about 10 percent ground water and 90 percent is surface water. [22]

Upper Valley Surface Water Resources

The centerpiece of the water picture in the Wood River Valley is the Big Wood River and the role it plays in the Upper Valley is especially important. Beginning at Titus Lake near Galena Summit, the river starts a 56 mile journey southward to Magic Reservoir. Over this course the river interacts with ground water as do all surface streams as they fall to lower elevations. High up near a river's headwaters it will "gain" from ground water seeping into its channel through banks and streambed but downstream this process will reverse and the river will start to "lose" water. It is through this recharge process the river contributes to the aquifer. Technically speaking, a river gains when the water table exceeds the elevation of the riverbed, it loses when the water table falls below the riverbed elevation. As the Big Wood River flows south it is clearly a gainer high in the mountains and then alternates for a transitional period between as both a gainer and a loser until it finally becomes to a losing river below Hailey. Overall, the river gains more than it loses in the Upper Valley.[23]

Twenty-one tributary drainages contribute stream flow and ground water to the river during its 36 mile reach from Titus Lake to the gauging station in Hailey. Each drainage adds water volume to the upper Big Wood River, but the major flows are contributed by surface and subsurface flows from the Deer Creek, East Fork, North Fork, Trail Creek, and Warm Springs drainages (Table 1). These five tributary streams drain 348 square miles of Upper Valley watershed and contribute about 242,000 af/y to the Big Wood River.[24]

Big Wood River flow measurements have been recorded historically by two gauges, one located near Sawtooth National Recreation Area (SNRA) headquarters (now defunct) and today's active gauge in Hailey. River measurements recorded between 1949 to 1971 at the SNRA gage listed an average annual minimum discharge of 86 cfs with a maximum of 270 cfs; average annual discharge for this period was 167 cfs. Corresponding measurements taken at the southern gauge for mean minimum, maximum and annual flows were 235 cfs, 831 cfs, and 490 cfs respectively or 350,000 af/y for the 1949 to 1971 period while 1916 to 1994 indicate less (286,000). Measurements at Hailey gauge for the 1993-94 period were in the 376,000 af/y range.

Upper Valley Ground Water Resources

The surface and ground water systems of the upper Wood River Valley are interconnected. As a result, it is difficult to discuss them as separate entities since alternating elevations in the water table and river heights can cause water to alternate from ground water to surface water and back again.

Table 1. Upper Valley Subwatersheds

Name – Description	Area in Miles^2	Area in Percent
Above North Fork	137	21.9
North Fork	41	6.6
Trail Creek	64	10.2
Eagle Creek	11	1.8
Lake Creek	15	2.4
Leroux Creek	1.8	0.3
Oregon Gulch	6.1	1.0
East Fork	86	13.7
Fox Creek	9.8	1.6
Dip Creek	1.4	0.2
No Name	4.9	0.8
Adams Gulch	12	1.9
No Name	2.5	0.4
Warm Springs Creek	98	15.7
Elkhorn Gulch	15	2.4
West Gimlet	11	1.8
East Gimlet	2.9	0.5
Greenhorn Gulch	24	3.8
Ohio Gulch	9.5	1.5
Indian Creek	14	2.2
Deer Creek	59	9.4
TOTAL	**626**	**100%**

Ground water also moves down tributary canyons just like their overlying surface streams. Estimates of underflow contributed by five of the major streams to the ground water system of the Upper Valley are given in Table 2.[25]

Table 2. Estimates of Upper Valley Tributary Underflows*

Location	Estimated Underflow (af/y)
Above North Fork	16,300
Warm Springs	2,900
Trail Creek	15,900
East Fork	19,000
Deer Creek	19,600

*The additive sum of underflow from these tributaries exceeds total underflow at Hailey due to "gainer/loser" interaction.

Upper Valley Water Use

Basically there are two types of water "use"---**consumptive** and **non-consumptive**. Hydrologists measure consumptive use similar to the way rainfall is reported. When we say it rained an "inch," this means rainfall is recorded as height of water covering a unit of area. In similar fashion, when the consumptive rate of a particular type of vegetation is said to be "12 inches," this means for each surface area unit of the vegetation---perhaps a square foot---a column of 12 inches of water will be transpired through the plant's roots and leaves per unit of time. For example, during a growing season suppose farmer pumps 652,000 gallons of water from an irrigation well and spreads it over one acre of land. This amount of water would equal the acre being covered with 24 inches of water or two acre feet of water. Further, scientists know this land and its crop will evapotranspirate (consume) 12 inches but the other 12 inches will percolate downward to the aquifer. Calculating consumed water is not always this simple as many complex factors can come into play but it is today's accepted practice to equate water evaporated and transpired (ET) as tantamount to water consumed. If the amount of water deposited by precipitation equals the consumptive loss then the water yield is zero! If precipitation, per unit of time, exceeds consumptive loss then a positive yield takes place and vice-versa produces a negative yield.

Upper Valley Population Estimates – Attempting to gauge patterns of water consumption and use cannot be done in a vacuum. For this reason, hydrologists rely heavily on the work of demographers and planners to establish the number of residences (DU), their occupants, and the rate at which they appear to be growing. Several studies try to pinpoint Blaine County's population and this *Summary* adopts statistics published by U.S. Bureau of Census (Table 3).[26]

Overall population estimates vary considerably depending upon methodology and the inclusion (or exclusion) of vacation homes and part time residents. In general, total county population is thought to hover between 17,000 and 19,000 persons in 1999. Adopting the Bureau of Census figure of 17,200 permanent county residents and suggests about 16,500 people live in the Wood River Valley and Bellevue Triangle. Of this number, 67 percent (10,915) are believed to reside in the incorporated cities of Sun Valley, Ketchum, Hailey, and Bellevue while the remaining 33 percent (5,600) are spread throughout the unincorporated sections of the Wood River Valley.

Within the Upper Valley we find the greatest concentration of human habitation. Bureau of Census data (1998), places the total permanent population of three incorporated cities of the Upper Valley at 9,300 and an additional 3,650 persons in the unincorporated sector. Overall, nearly 13,000 individuals make the Upper Valley their primary home. Drawing from different sources, the Wood River Action Plan (WrRAP) at first places the Upper Valley's municipal population considerably higher (16,317) but then discounts their estimate 32 percent to remove the impact of part time residents and vacation homes (Table 3).

Upper Valley Water Use in Municipal Sectors – There are two ways to approach estimating water consumption in municipalities in the Upper Valley.

Table 3. Three Estimates of County Population

Government Unit	WrWRAP (adjusted)*	WwRAP (unadjusted)	Bureau of Census
Bellevue	1,718	1,728	1,592
Carey	417	417	513
Hailey	5,789	5,931	5,554
Ketchum	3,873	6,010	2,759
Sun Valley	1,485	4,376	1,010
Unincorporated County	5,661	5,939	5,772
TOTAL	**18,943**	**24,401**	**17,200**

*Adjusted estimates derived by removal of vacation homes and part time residents; Unadjusted estimates derived by multiplying reported dwelling units by persons per unit.

One way is by looking at the average per capita consumption and measures "gallons per capita day" (gpcd) while the other school contends water usage is better understood by counting residences (dwelling units). With respect to the Wood River Valley local planners and water professionals tend to favor the former while IWRRI the latter. Water scientists prefer "residence" as the unit of analysis for measuring water usage for two reasons. First, per capita water usage isn't perhaps the best indicator for understanding water consumption. Water used for domestic purposes inside the household (i.e. toilet, laundry, shower, dishwashing), isn't really consumed but practically all of this water is returned to the watershed. Second, the amount of water consumed outside the household for landscape irrigation tends to be the same regardless of how many individuals reside in the home. For that matter of fact, they argue, this consideration also extends to vacation homes since they are still irrigated whether or not the homeowner is present.

Local planners and water officials do, however, tend to take per capita water usage into account and Blaine County's consumption is high compared to the rest of the United States. Other similar arid mountain communities in the High Sierra and Colorado Rockies have comparable rates due to the fact that water is perceived to be abundant, municipal use is un-metered, and landscaping can be extensive and thirsty. The "typical"

American's annual use nationwide, however, is much lower and usually between 160 to 180 gallons a day in contrast to the Upper Valley where this figure ranges from 400 to 600 gallons. In Hailey, for example, even though per capita consumption has dropped in recent years it still hovers between 450 to 500 gpcd per day and can spike to nearly 1500 gpcd during summer months with irrigation. Other Upper Valley municipalities are Sun Valley (650 gpcd) and Ketchum 388 gpcd).

Water professionals usually assume that an acre foot of water is enough to serve two families for a year, but in this valley, average consumption rates trend to 5 acre feet per year, enough for ten average family households. When water is used at home, about half goes inside the home (most of which returns to the water resources system), the remainder outside. The largest two consumers of domestic water inside the home are the toilet (26 percent) and the shower (18 percent). Outside the home Idaho law limits domestic households from using more than 13,000 gallons a day for landscape irrigation.

For all sorts of reasons, cities favor using ground water---as opposed to surface water---for domestic purposes. Understanding municipal use in the Upper Valley requires the creation of an annual per capita water use estimate. Yet compilation of this figure is complex for several reasons. First, it is true Upper Valley municipalities have a core resident population but they also have part time residents with vacation homes as well as tourists. Second, the rate of water use varies considerably from summer to winter as well as from wet years to dry years. To tackle this problem ***Phase II*** was compelled to make selected assumptions about population size and water consumption. There are at least four different ways to derive water use/consumption statistics depending upon various methodologies (see Table 4.) In fact, the situation is made even more complicated because MODFLOW's 1993-94 reference year counted half of Hailey as being in the Upper Valley and the other half as being in the Lower Valley.

Method One – The first method was adopted by IWRRI in ***Phase II.*** This technique assumes the cities of Sun Valley, Ketchum and Hailey use no surface water to meet customer demand and withdraw 8,800 acre feet from the aquifer to meet annual

Table 4. Estimates of Upper Valley Municipal Water Use (af/y)

	Method 1		**Method 2**		**Method 3**		**Method 4**	
Municipality	Diverted	Consumed	Diverted	Consumed	Diverted	Consumed	Diverted	Consumed
Ketchum	3,244	481	3,120	468	3,478	522	3,328	499
Hailey	3,201	472	1,356	203	3,384	507	1,472	339
Sun Valley	2,361	347	1,524	229	2,538	381	1,600	122
Totals	8,806	1,300	6,000	900	9,400	1,410	6,400	960

demand or 7.86 million gallons per day (gpcd).[27] Of this amount, 7,500 af/y (85 percent) is returned to the water resources system in the Upper Valley while 1,300 af/y (15 percent) is consumed. These figures were derived using demographic data which did not exclude vacation homes and part time residents and assumed an "across the board" water usage rate of 482 gpcd.[28]

Method Two - A second technique "adjusts" population values by discounting the net effect of part time residents and vacation homes while still adopting the 482 gpcd estimation of daily per capita water withdrawal. This approach suggests an annual water diversion from the Upper Valley aquifer of 6,000 af/y with an associated consumption of 900 af/y. A problem with this method is if vacation homes are irrigated in the summer during the homeowner's absence the amount of consumed water may be underestimated.

Method Three – A third approach incorporates more city specific information about actual water usage rates (i.e. Sun Valley 650 gpcd; Hailey 540 gpcd, Ketchum 388 gpcd) while using the unadjusted estimates of population. In this way water usage is suggested to be 9,400 af/y of which 1,410 af/y are consumed.

Method Four – The final technique removes the part time residents from the equation and simultaneously factors in the city specific rates of consumption resulting in 6,400 af/y withdrawn and 960 af/y consumed.

Upper Valley Water Use in Rural Sectors – Given the average altitude and typical of the Upper Valley, land covered with range grass and brush has an annual consumptive use (ET) of approximately 12 inches of water per unit of land surface. The same land under cultivation with water intensive crops would consume anywhere from double to triple this amount (Table 5). For this reason, the largest single consumer of water in the Upper Valley is irrigated agriculture in the rural areas and in order to understand patterns of water consumption calls for a brief discussion of irrigation from Hailey northward.

Pinpointing changes over time in the Upper Valley's irrigated acreage is not easy and potential exists for over estimation.[29] Adding complexity are the varying methods of estimation as well as the fact the amount of irrigated acreage changes from one year to the next. In addition, growers plant different vegetation with slightly different rates of consumption making it difficult to state precisely what water consumption rates are at any point in time.[30] A general consensus holds that farming on lands outside the three municipalities in the Upper Valley has decreased from over 9,000 acres in 1950 to about 6,400 acres today. This decline does not necessarily convert to a net decrease in water because much of the former crop land is converted to landscape. ***Phase II*** states about 46,000 af/y are diverted to rural sectors of the Upper Valley. Viewed differently, rural homeowners in the Upper Valley apply 41,100 af/y for irrigation and use 4,800 af/y in their homes. With respect to the water taken for irrigation, about 4,930 af/y (12 percent) comes from ground water and remaining 36,100 af/y (88 percent) from surface diversion. Of the total water diverted for rural use 18,300 af/y (38 percent) is considered "lost" to evapotranspiration while 28,800 af/y (62 percent) returns to the water resources system of the Upper Valley. Table 5 compares consumption use for different types of vegetation in proximity to Ketchum.[31]

Creating consumptive use coefficients allows the comparison of water usage per unit of land expressed in terms of water consumed; for example, a golf course can be compared with a ranch of similar size. Table 6 compares two parcels of equal size (160 acres): a ranch and a golf course. Suppose, the golf course has 20 acres of buildings and roads while the ranch has only 5 acres set aside for similar usage. And 130 acres of the golf course are put into irrigated landscape while the ranch only uses 1 acre. In this manner, Table 6 contrasts water use on identical plots of land where, interestingly the annual amount of consumed water is nearly identical. Of course these approximations

Table 5. Estimates of Upper Valley Rural Consumptive Use

Category	**Consumptive Use** (inches)
Alfalfa	26
Pasture	27
Blue Grass	30
Forested landscape	25
Brush/rangeland	12

are based upon specific assumptions of what comprises a "typical" pattern of allocation for a golf course or ranch.

Table 6. Comparative Consumption of Water for a Ranch versus a Golf Course (in acres)

Parcel Allocation	**Ranch (out of 160 acres)**	**Golf Course (out of 160 acres)**
Buildings and Roads	5.0	20.0
Irrigated Landscape	1.0	130.0
Irrigated Pasture	75.0	0.0
Irrigated Alfalfa	75.0	0.0
Non irrigated	4.0	10.0
Consumptive Water Use	**26.3 inches**	**26.6 inches**

Upper Valley Buildout Estimates and Water Use

In 1998, Benchmark Associates completed their land capacity ("buildout") study, updated in June of 1999 by Blaine County planners. The Steering Committee requested ***Phase II*** to integrate selected aspects of the aquifer investigation with the county buildout study. As with so many aspects of this study several factors make this integration complicated: (1) the county's study did not specify if lands converted to development were to be drawn from natural vegetation or existing acreage; and (2) it did not specify the size of the parcels to be converted to development. To address these issues, IWRRI estimated comparative water consumption values for six parcel sizes based upon assumed configurations of infrastructure, landscape, parcel size, and croppage.[32] For example, it was assumed that a "small" parcel of 0.5 acres would have 0.2 of an acre in buildings and roads, another 0.3 acres in irrigated landscape and no consumptive water areas for pasture, alfalfa, or non irrigated acres. Similar estimates were also made for the other five parcel sizes (see Table 7).

Table 7. Estimates of Consumptive Water Use for Selected Rural Parcels

	Small	Medium	Large	Ranchettes	Ranch	Golf Course
Parcel Size (acres)	0.5	0.7	1	5	160	160
Buildings & Roads	0.2	0.2	0.2	0.2	5.0	20.0
Irrigated Landscape	0.3	0.5	0.8	0.8	1.0	130.0
Irrigated Pasture	0.0	0.0	0.0	4.0	75.0	0.0
Irrigated Alfalfa	0.0	0.0	0.0	0.0	75.0	0.0
Non-irrigated acres	0.0	0.0	0.0	0.0	4.0	10.0
Consumptive Use (inches)	***19.1***	***22.7***	***25.5***	***27.5***	***26.3***	***26.6***

Interpreting Table 7 calls for first looking at the parcel size (given in acres) and then dropping below to read its estimated consumptive use given in inches per unit of surface. For example, the "small" (half-acre) parcel may consume 19.1 inches of water given its particular configuration of landscape, buildings, and vegetation. This water consumption coefficient can be used to compare water use per unit of surface compared to, say, a medium sized five acre parcel consuming 22.7 inches of water per unit of surface. In this manner, the values in Table 7 reflect consumptive use per unit of area: not volume, so Table 7 does not say a "Ranch" of 160 acres consumes less total annual volume (26.3 inches) than a 5 acre "Ranchette" (27.5 inches). Instead, Table 7 projects water use on a 5 acre Ranchettes is slightly more intense per unit of surface area than on the larger Ranch. From the values in Table 7, the lowest consumptive use per gross area is associated with small residential lots and the largest is associated with 5 acre parcels.

Upper Valley Water Use in Rural Buildout Subareas – According to the county's land capacity study, two buildout regions---Subareas A and B---were identified as being candidates for future development in the rural portions of the Upper Valley (Figure 5). There are 1,370 existing residences (DU) in the rural sectors defined as Subareas A and B with room for an additional 2,420. Overall, this means there is an estimated future capacity for 3,790 in the Upper Valley according to county planning.

Adopting these figures along with certain assumptions, ***Phase II*** compared water consumption associated with varying parcel sizes.[33] Table 8 represents what happens when a 160 acre tract of previously irrigated land is converted to 156 small (one acre) parcels, 31 medium (5 acre) parcels, or 15 large (10 acre) parcels. In the "Before" situation, a single 160 acre tract of irrigated crops annually consumes 26.3 inches, or 350 af, of water. Should this tract be replaced by a development having 156 parcels (one acre in size with the assigned configurations of water use by researchers) the annual water consumption drops to 25.1 inches per parcel.[34] Converting the 160 acre tract from crops to homes reduces water consumption about 1.2 inches per parcel, or 16 acre feet for the entire tract. Consumed water volume would decline from 350 af/y to 334 af/y.

Table 8. Comparison of Water Use for Parcels Replacing 160 Irrigated Acres

		Parcel Size		
	Before	**After Conversion from Irrigated Acreage**		
	(160 acres)	Small (1 acre)	Medium (5 acres)	Large (10 acres)
Number of Parcels	1	156	31	15
Consumptive Use:				
Total (inches)	26.3	25.1	27.1	26.8
Change (inches)		-1.2	3.7	5.0
Volume Use:				
Total (acre feet/year)	350.0	334.0	361.0	357.0
Change (acre feet/year)		-16.0	+11.0	+7.0

Phase II also examined what would happen if a 160 irrigated tract was converted to the medium and large parcel sizes. Substituting an irrigated tract with 31 medium parcels increases water consumption by 271 inches per acre raising total water consumed from 350 af/y to 361 af/y (+ 11af/y). And, again from Table 8, it can be seen that converting the same 160 irrigated tract into 15 large parcels results in an increase of consumed water by 0.5" per acre or 357 (+ 7) af/y.

When reviewing these forecasts, bear in mind an existing 160 acre tract of irrigated acreage comes with previously established water rights attached to the land; rights which are transferable by law. This means the developer brings to the new subdivision a right to take advantage of the same water that previously went to crops.[35] ***Phase II*** also explored consumptive water use associated with varying parcel sizes when converted from natural vegetation. Utilizing a similar methodology, water use values were computed for replacing 160 acres of natural range and brush with small, medium, and large parcels (Table 9). The yearly consumptive use of a 160 acre tract of natural vegetation is 12 inches per acre (or 160 af/y), exchanging this land into small parcels boosts consumptive use to 19.3 inches (+7.3") per acre. As above, conversion to medium parcels raises consumptive use to 13.5 inches per parcel size and for large units to 12.7 inches per parcel size.

Part of Table 9 admittedly can be confusing, especially with respect to changes in consumptive use for medium and large parcels. Even though parcel sizes are enlarged from 1 acre (small) to 5 acre (medium) and 10 acre (large) tracts, the "Change" in consumptive use values remains constant.[36] Due to the Snake River Basin Adjudication, IDWR has placed a maximum limitation of 0.5 acre for irrigated landscape on new developments. In other words, when a tract of land is converted from natural vegetation

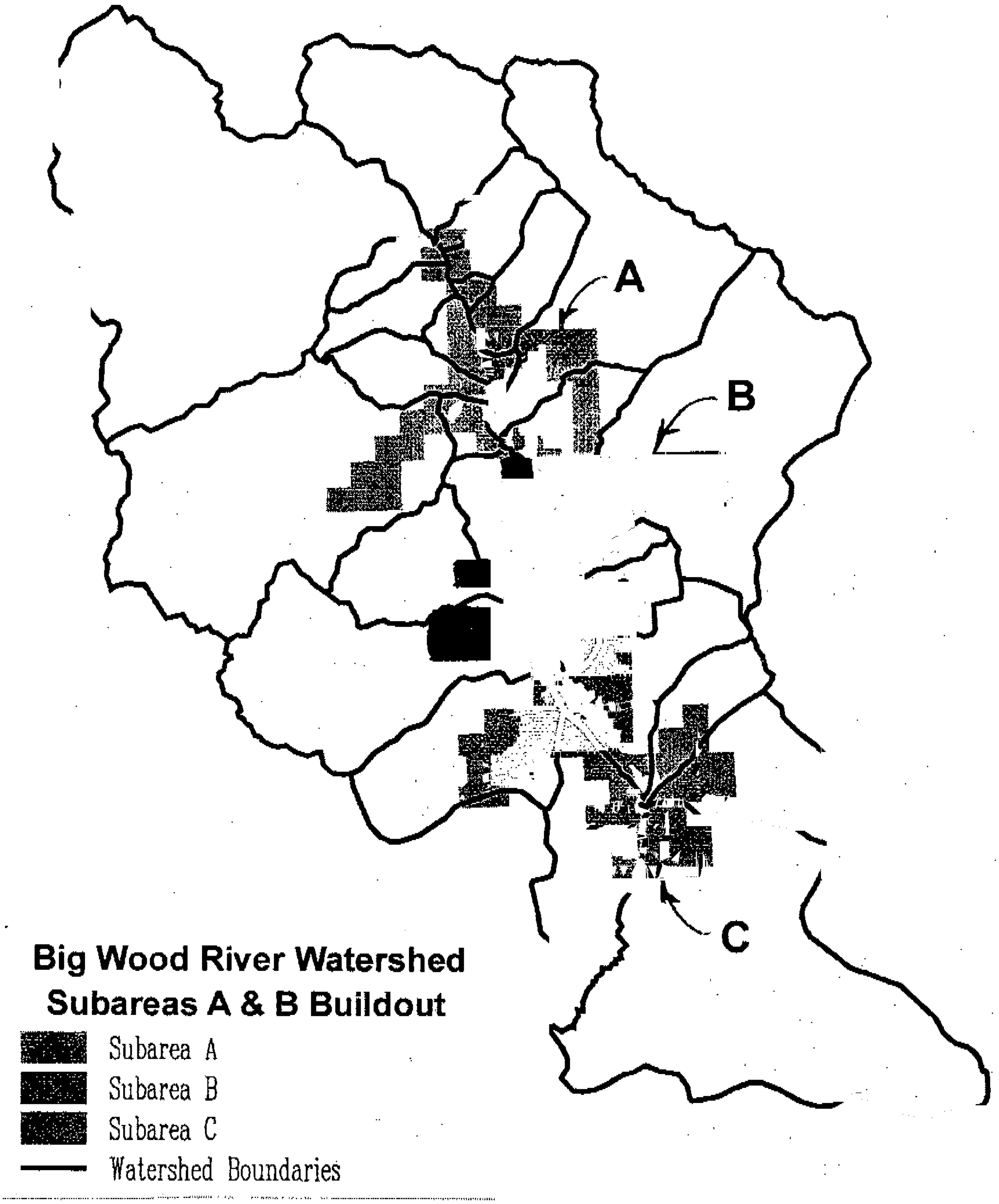


Figure 5. Location of Blaine County Buildout Subareas

(with no existing prior water right) no more than half an acre can be irrigated per parcel regardless of parcel size. For this reason, the change in "Consumptive Use" category in Table 9 reflects an impact of +7.5 inches per parcel no matter how large the lot.

Table 9. Comparison of Water Use for Parcels Replacing 160 Acres of Natural Vegetation.

	Parcel Size			
	Before	**After Conversion from Natural Vegetation**		
	(160 acres)	Small (1 acre)	Medium (5 acres)	Large (10 acres)
Number of Parcels	1	156	31	15
Consumptive Use:				
Total (inches)	12.0	19.3	13.5	12.7
Change (inches)		7.5	7.5	7.5
Volume Use:				
Total (acre feet/year)	160.0	257.0	180.0	169.0
Change (acre feet/year)		+97.0	+20.0	+9.0

*Current Idaho water policy disallows more than 0.5 acres of irrigation per parcel regardless of parcel size. For this reason, the small parcel size was modeled not to exceed this amount and the medium and large parcel sizes were held constant and 0.5 acres of 15.5 acres and 7.5 acres respectively.

In general, ***Phase II*** constructed a generalized view of today's estimated water use associated with buildout patterns in the rural sections of the Upper Valley.[37] This *Summary Report* extended this analysis by making linear ratio assumptions to derive projected uses at buildout and presented in Table 10.[38] Caution should be emphasized, however, in generalizing too much from these figures. On one hand these figures indicate that if the number of residences in the rural sector of the Upper Valley increase nearly two thirds the estimated impact on the Upper Valley's water resources remains low. On the other hand, many factors could affect this outcome such as whether or not the land is converted from natural vegetation or irrigated cropland or the introduction of alternative land use assumptions. In addition, water quality concerns could develop outweighing water quantity issues.

Table 10. Estimates of Future Water Diversion & Use in Rural Portions of the Upper Valley.

Status	Dwelling Units	Diversion (af/y)	Consumption (af/y)
Today	1,370	4,760	2,680
Buildout	3,790	13,200	7,440

It is difficult to forecast whether or not proposed developments would come from natural vegetated lands or from existing irrigated lands with water rights. Overall water consumption will be affected by parcel size and whether or not the land is developed from either existing irrigated cropland with water rights or from natural vegetation. With this variance in mind, land use planners and concerned citizens are urged to study the coefficients provided in the category of "Change in Consumptive Use" in Tables 8 and 9 above and Table 34 in ***Phase II***. The "Change in Consumptive Use" estimates provide "utility" numbers to weigh the comparative impact of development when combining small, medium and large parcels; in a sense they can be mixed and matched to estimate consequences of future projects of a complex nature.

Upper Valley Water Use: Summary

All in all, water diverted from surface and subsurface supplies for human at Hailey and above was set at 54,700 af/y of which 38 percent (18,200 af/y) is consumed and 62 percent (36,500 af/y) returned to the watershed. Even though the long range picture appears to indicate a steady decline of irrigated acreage in the Upper Valley it still diverts the lion's share; approximately 46,000 af applied annually to irrigated acreage while 8,800 af goes to municipalities. Of the 54,700 af/y diverted for human use about 25 percent comes from ground water (14,000 af/y) while 75 percent (41,000 af/y) is drawn from the Big Wood River, Trail Creek or East Fork. Viewed from an alternate vantage shows irrigated acreage in the Upper Valley takes mostly surface waters (36,000 af) as opposed to ground water (5,000 af/y). Just the opposite is true for cities as they tend to draw almost entirely upon ground water to meet an annual domestic demand of 8,800 acre feet. During the 1993-94 reference year, humans seem responsible for the consumption of approximately 3 percent (18,200 af/y) of the entire Upper Valley waters (699,000 af/y) while natural vegetation uses 97 percent (681,000 af/y). Lastly, today's consumptive use of 2,680 af/y and the anticipated consumptive use for buildout in rural areas of 7,430 af/y is a small part of the estimated water yield of the Upper Valley.

WATER RESOURCES OF THE LOWER VALLEY

Clear differences exist between the Upper Valley and the Lower Valley with regard to their respective patterns of water use, climatology, and communities. Probably the most obvious contrast centers upon economics, the Lower Valley resting on a thirsty agrarian/agricultural base while the Upper Valley needs domestic and landscape water for its tourist/recreation focus. Another dissimilarity inheres in relative aridities. While water demand is substantially greater in the 255 square miles Lower Valley, most precipitation falls north of Hailey. The average annual precipitation of 13 inches in the Lower Valley converts to 219,000 af compared to the Upper Valley's 1.1 million af/y.[39]

Lower Valley Surface Water Resources

Lower Valley surface flows in the Bellevue Triangle fall into three distinct, but related, categories: the Big Wood River, irrigation diversions through canals, and lastly---through its springs and creeks---Silver Creek itself. Given the Lower Valley's aridity and agricultural base, the best point of departure for understanding water resources in the Lower Valley/Bellevue Triangle is with the Big Wood River.

Big Wood River – The Big Wood River receives most of its volume from the Upper Valley watershed and crosses into the Lower Valley at Hailey. Monitoring began in 1915 with the placement of a stream recorder near the Croy Street bridge. Reviewing these records reveals great variability in river flows depending upon climatic conditions. In 1931, for example, the river flowed less than 100 cfs while in 1983 flow volume exceeded 800 cfs. For the period between 1916-1994, the river measured at Hailey has averaged about 520 cfs annually or 375,000 acre feet. From Hailey the river flows south to a point below Bellevue where it turns southwesterly through the Poverty Flats region and follows along the southeastern edge of the Smoky Mountains.

In the river reach from Hailey to Stanton Crossing, the water table alternates between rising above and falling below the river channel. Overall, however, the Big Wood River is clearly a losing stream for most of this distance. As mentioned above, it is not uncommon for the river to run dry below Glendale Bridge during peak summer irrigation months only to re-emerge several miles further south in the form of seep springs or through waters contributed from the By-Pass Return Canal. Measurements recorded by the station at Stanton Crossing show the river's lowest flow was 40 cfs (29,400 af) in 1992 and its highest was 590 cfs (425,000 af) in 1983; the river's average annual flow is computed to be 397 cfs or 287,000 acre feet a year.[40]

Water is withdrawn from the Big Wood River in the Lower Valley through three ways, evaporation, seepage and irrigation diversion. In the 1993-94 reference year, the Hailey stream gauge measured 382,000 af yet only 223,000 af exited the basin at Stanton Crossing underscoring the amount of water lost from the river south of Hailey. While no figures exist to estimate river evaporative losses in the Lower Valley approximations are available for seepage and irrigation diversions.

Seepage from the river to the aquifer between Hailey and Glendale Bridge was computed to be 79,200 af/y for the reference year.[41] No doubt some amount returns to the Big Wood River via springs and streambed flow, however, most serves to recharge the Bellevue Triangle/Silver Creek aquifer. Put differently, 217 acre feet of water each day, percolates down through the river's porous streambed and moves toward the southeast and Silver Creek.

Irrigation diversions comprise another way the river loses water. Headgates are usually opened in May and water is diverted through a system of unlined main and lateral canals. Great variability exists on the amount of water diverted for irrigation from the river usually depending upon snowpack and precipitation.

During the reference year, 101,100 af were shunted from the river through the four large "indicator canals (District 45, Black's Ditch, Glendale and Baseline) for irrigation on croplands. About 99,700 af went to crops while a smaller amount (1,400 af) went to recharge pits; much of this water percolates down through the unlined canals and crop fields to add to the Bellevue Triangle/Silver Creek aquifer (Figure 6). The topic of irrigation diversions from the river and their effect upon Silver Creek are discussed in more detail below (see *Lower Valley Ground Water Resources*).

Lower Valley Springs and Creeks – The water table elevation exceeds surficial elevation along the southern portion of the Bellevue Triangle thus creating spring-fed creeks. While a few of these creeks emerging east of Highway 75 flow southwest to rejoin the Big Wood River, the preponderance of spring flow is to the southeast. Emerging as springs, Buhler Drain, Patton, Cain, Mud and Channey Creeks rise to flow into Stalker Creek and on into Silver Creek. A little later, Thompson and Wilson Creeks flow into Grove Creek and then join Silver Creek. Lastly Loving Creek joins the main stem just below The Nature Conservancy's Visitor Center. Taken as a whole, these tributaries become the headwaters of Silver Creek as illustrated in Figure 6.

Silver Creek Surface Flow – The headwaters of Silver Creek begin in the May Ranch (Stalker and Mud Creeks) locale and are joined soon after by its largest contributor---Grove Creek---and then Loving Creek. Thus the true headwaters of Silver Creek are the springs created by precipitation, ground water underflow from the Upper Valley, and to some extent by irrigation diversions. Silver Creek is believed to produce an average annual flow somewhere between 85,000 af/y to 100,000 af/y; in the 1993-94 reference year it was 91,100 acre feet.

Research confirms Silver Creek tends to rise and fall in concert with flows of the Big Wood River. Typically, Silver Creek flows begin rise in June and peak in late summer during August and September and soon thereafter begin to decline again. During the dead of winter, flows are minimal with a brief spike occurring in late February due to early snowmelt but the early spike tapers off and the cycle begins anew.

USGS flow records date back to the 1920s. Originally, a stream gauge was located downstream of Picabo but in 1963 USGS suspended operations and no measurements were taken. In 1975, USGS resumed data collection but at a new location miles upstream at Sportsman's Access. This decision presented difficulty for ***Reports*** because not only were data lost due to the hiatus in record keeping but relocation of the stream gauge makes comparative analysis very difficult since irrigation diversions take place between the old and new positions as well as surface/ground water interaction.

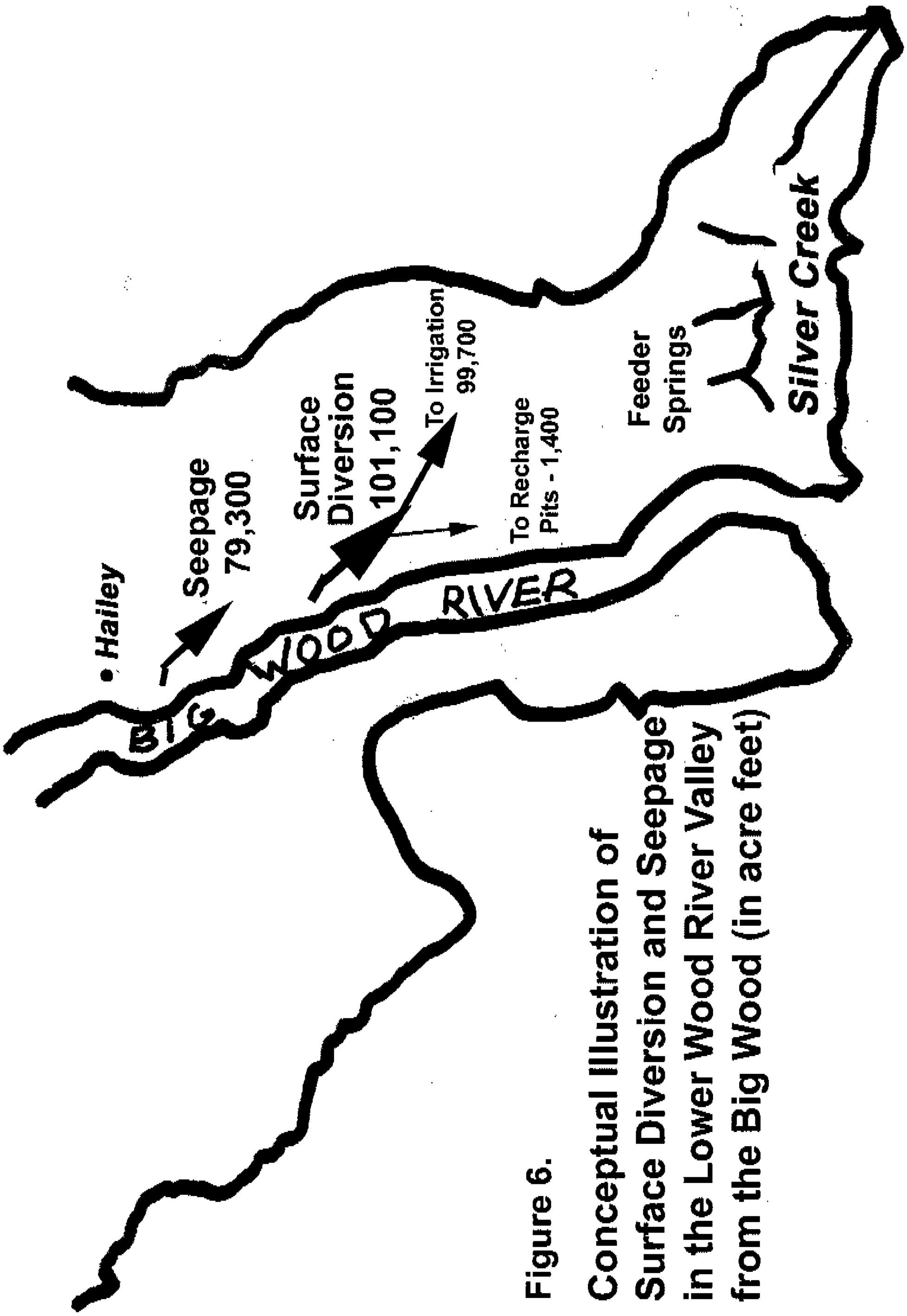


Figure 6.

Conceptual Illustration of Surface Diversion and Seepage in the Lower Wood River Valley from the Big Wood (in acre feet)

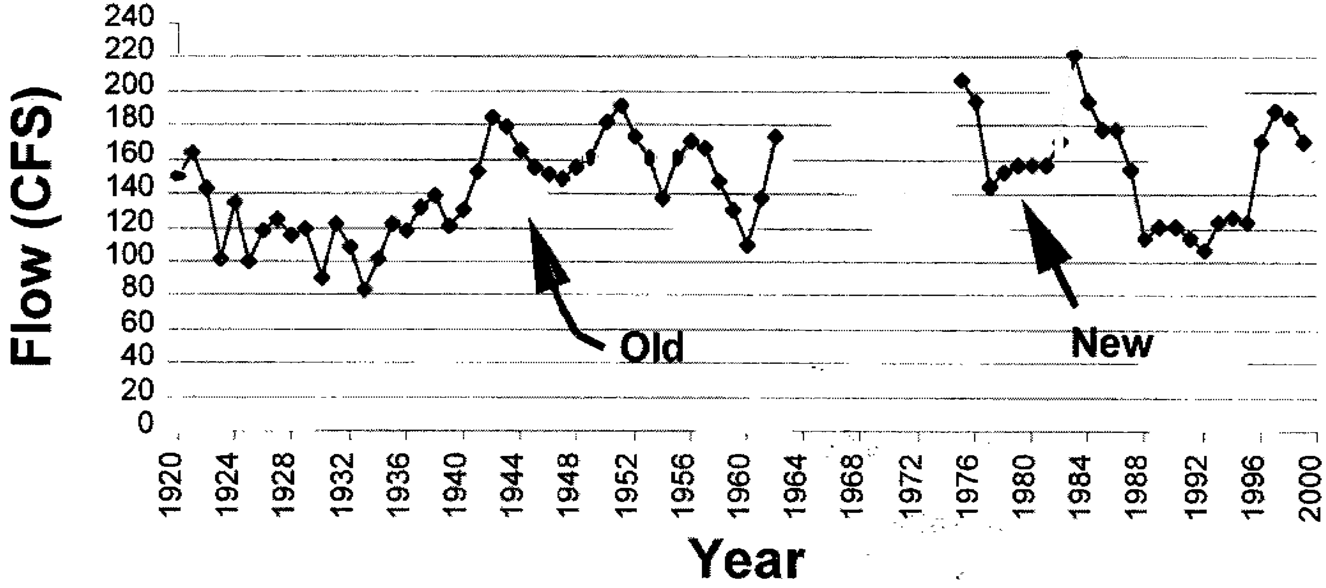
Records indicate, if anything, wide variation in Silver Creek flows. Data from the original gauging station suggest average annual flows in Silver Creek (below Picabo) were fairly constant at about 160 cfs. When the new gauge was installed flow levels were also in the 160 cfs range but slowly increased until they peaked in the bumper water years of 1983-84. Low flows were encountered in the late 1920s and early 1930s as well as 1960. Then in the early 1990s, Silver Creek flows plummeted to low flows again but this time being recorded by the new gauge and its new location. Between 1988 and 1993 average annual flows hovered in the 120 cfs range but more recent wet years (i.e. 1996) have witnessed a significant recovery in Silver Creek flow. Since 1997, average volume of Silver Creek has remained in the 180 cfs range, a marked increase from the earlier part of the decade (Figure 7).

Lower Valley Ground Water Resources

The ground water basin in the Lower Valley receives its water from several sources: underflow from the Upper Valley, river seepage, precipitation, and percolation from irrigation. Speaking strictly about the MODFLOW study site, ***Phase I*** estimated 22,400 acre feet of subsurface water flowed from the river and into Silver Creek's recharge zone but ***Phase II*** revised this amount upward to 79,200 acre feet. Increasing the estimation of seepage was needed in order to get the MODFLOW model to converge during the calibration period, or, in other words, given the know laws of hydrology this figure had to be higher or the model would not work properly. Precipitation was thought to be 51,300 af and underflow 34,800 af. The amount of inflow from irrigation diversion was approximated by ***Phase II*** to be 99,700 af.

Within the study site about 30,000 acres of cultivated land are irrigated by thousands of acre feet of water diverted annually from the Big Wood River. These diversions from the river help to recharge Silver Creek's headwaters in two ways: through the canals bringing the water as well as the direct application of irrigation onto

Figure 7. Average Annual Flow of Silver Creek 1920-1999 (Old and New Gauging Stations)



New gauging station is 6 stream miles upstream.

the land, most of which percolates into the water table only to re-emerge in the discharge springs forming Silver Creek. These irrigation diversions from the Big Wood River are thus linked inextricably with Silver Creek and discussion has been stimulated since it appears surface diversions from the river are declining. Public opinion is somewhat divided with respect to this phenomenon giving rise to two interpretations: (1) a decline in surface diversion could mean less water for Silver Creek's recharge zone; or (2) a decline could mean more water would remain in the Big Wood River below Hailey.

From the information presented in ***Reports*** it is difficult to ascertain exactly how much surface diversions have decreased. At first, ***Phase I*** used data from an earlier study (1975) to compare with information gathered during the 1993-94 reference year and stipulated the reduction was substantial, from 142,000 af in 1975 to 92,000 af in 1993. This statement, however, has been subsequently revised because it did not involve comparable units of analysis.[42]

Other difficulties are encountered when attempting to "tease" out more information from ***Reports*** concerning surface diversions from the Big Wood River onto Silver Creek's recharge zone. Comparable data for the intervening years from 1975 to 1993 are scant. The best that can be done is to make point to point comparisons for 1975 and 1993; caution is warranted because the study sites are not comparable in size or periodicity. Moreover, researchers are convinced surface irrigation from the Big Wood River onto the Silver Creek recharge zone has diminished since 1975 but they have not pinpointed an exact estimate of decrease.

Diminishing use of surface diversions onto the Bellevue Triangle can be associated with several factors. Among these reasons would be a slight decrease in acres irrigated, introduction of less water intensive crops, and conversion of land to non-agricultural uses. The most likely explanation of the tendency to use less river water is the "double whammy" of adopting more efficient irrigation practices and the pumpage of more groundwater.

Trend analysis of irrigation practices and ground water pumpage presents the same difficulties described above. ***Phase I***, however, does estimate the percent of land watered by sprinkler irrigation rose from 13 percent in 1975 to 74 percent in 1993 within the Lower Valley. Carrying an equally important consequence for Silver Creek recharge is the growing tendency to use ground water for irrigation, especially in dry years. Historically, ground water was used mainly as a supplemental source of irrigation water but both ***Phase I*** and ***Phase II*** report ground water is used increasingly as a primary source of irrigation water. In 1993, about 53 percent of cropland in the triangle was irrigated by ground water while the remaining 47 percent came from canal diversions from the Big Wood River.

Lower Valley Water Tables – Certainly a key concern revolves around what has been happening to ground water tables over time. The answer to this question fluctuates, of course, depending upon the time period called into focus. If we compare today's ground water levels with those of aboriginal times---after human presence but before irrigation diversions---then we are safe in assuming the water tables are higher today in the Lower Valley aquifer due to the introduction of artificial irrigation diversions late in the last century. If we compare today's water tables with those of the 1950s---a period of maximum irrigation diversion---then they are likely to be somewhat diminished.

What is difficult to disentangle is the net effect of surface irrigation as distinct from climatic conditions. Put in other words, how much of the variance in water tables is attributable to humankind and how much to the natural processes of precipitation, seepage from the river, and underflow? Water tables and spring flows tend to rise when water diverted for irrigation is placed onto the recharge zone. The amount of water available for irrigation diversion, however, is, itself, a function of precipitation and how much moisture has fallen as snowpack.

One exception to the precipitation/diversion/water table connection occurred in the early 1980s. At this time Big Wood River flows were high due to a very wet winter but irrigation diversions from the river were not. Perhaps a possible explanation to this seeming exception is tied to the fact the immediately preceding years had been very dry (1977-80). During this drought farmers had begun to develop ground water in an effort to offset low diversion potential and were encouraged to do so by state policies encouraging this alternative. Thus in the first year out of one of the worst droughts of record growers probably did not return as quickly to surface diversions but used their newly installed ground water systems. In any event, the normal pattern of primary reliance on surface diversions soon resumed. It should be added that IWRRI researchers believe there is an increasing tendency to use ground water less as a supplemental source and more as a primary source.

On a seasonal basis, water tables fluctuate in both the confined and un-confined aquifer during a calendar year. These fluctuations are more pronounced in the un-confined aquifer where the seasonal variance is greater than the confined aquifer.

Looking at water tables over the years shows a general decrease in the last quarter century. ***Reports*** examined ground water depth measurements in 18 observation wells from 1975 to 1993 and determined the un-confined water table aquifer had declined about 1 foot while the artesian heads---water tables in the confined aquifer---had fallen slightly more.[43]

Ground water fluctuations taking place within a twelve-month cycle exhibit a relatively clear pattern depending upon location and time of year. During the April 1993 to April 1994 reference year, ground water measurements were taken from 80 wells at four time periods. Additionally, two observation wells were chosen for chronological analysis (1954 to 1993); one, an artesian well at Punkin Center drawing form the confined aquifer, the other pulling from the water table aquifer.[44] Data collected from well measurements indicate water levels rise and fall in response to seasonal precipitation and irrigation with maximum water levels usually happening in late June or early July depending upon irrigation diversions. On the whole, water table responses in the alluvial (water table) aquifer are more dramatic in magnitude than responses in the confined aquifer. This means the confined aquifer does not have the same range of response to seasonal variation observed in the unconfined aquifer. During summer months, when pumpage is high, the unconfined aquifer water table drops as much as 25 feet while decline in the confined aquifer remains muted in the 2 to 3 foot range. Water table response in the southern portion of the unconfined aquifer tends to be lagged about two weeks behind measured effects in wells to the north. Subsidence of water tables in the unconfined aquifer continues through the winter until the middle of February when a "spike" occurs reflecting snowmelt and surface runoff. This rise in water table gradient continues until early April when it begins to fall off again. Continued decline occurs until late May and early June when irrigation diversions begin anew with the commencement of growing season. Beginning in July, water levels once again begin to slowly diminish until the end of harvest at the onset of autumn. Maximum fluctuations in ground water levels take place in the Poverty Flats and Picabo areas (36 and 18 feet respectively) while minimum fluctuations of 5 to 10 feet occur throughout the southern part of the area.[45]

Lower Valley Water Use

Consumptive water use in the Lower Valley is considerably different than in the Upper Valley. In the Upper Valley, for example, only 33 percent of water diverted is consumed compared to the Lower Valley's consumption rate of 60 percent. What explains this difference in water use between the two regions are variations in human population, climatology and economics. The more arid and less populous Lower Valley has an infrastructure founded upon farming and agriculture while the more urban and wetter Upper Valley is oriented toward recreation and tourism.

Lower Valley Population Estimates – The U.S. Bureau of Census places about 16,500 people residing in the Wood River Valley including the Bellevue Triangle. Of this number, 32 percent (5,270) live between the southern half of Hailey (2,780) and Bellevue (1,590). Another 900 persons are believed to be in the unincorporated portion of the Bellevue Triangle. The adjusted WrWRAP survey places overall population for the Lower Valley slightly higher (5,590).

Lower Valley Water Use in Municipal Sectors – Unlike the Upper Valley, the Lower Valley tends to have a more stable, year around, residency with fewer vacation and part-time residents and thus the effort to approximate municipal water use in the Lower Valley is not as complicated. In the case of Bellevue, no volumetric records were readily available so researchers had to construct a reasonable picture of water diversion and consumptive use. Bellevue is thought to divert annually 1,200 af/y from wells and one spring while discharging treated effluent in lagoons located in the Poverty Flats area west of Highway 75. This figure was derived by multiplying the number of dwelling units (630) by the average number of individuals housed (3.2) by the average annual daily diversion (500 gpcd). Of the 1,200 af/y diverted by Bellevue, 250 af/y are thought to be lost to ET which is 38 percent of the total municipal water consumption of the Lower Valley.

Hailey records for the 1993-94 period show it diverted 3,200 af/y from its wells located at River Street, 3rd Avenue, and Woodside plus Indian Springs. Since---for analytic purposes---only half of Hailey is considered to be within the Lower Valley, its adjusted usage is set at 1,600 af/y. Hailey discharges its effluent by either returning it to the Big Wood River via the Riverside Treatment plant or spreading it over a leach field from the Woodside Treatment Plant.[46] Of the 1,600 af/y withdrawn from Lower Valley water resources, Hailey is believed to return 75 percent (1,190 af/y) to the water system while consuming 25 percent (410 af/y).

Overall, 23 percent (660 af/y) of the 2,800 af/y diverted by Bellevue and Hailey is consumed and 77 percent (2,140 af/y) is returned to ground water recharge. Placed in a alternative framework, the combined flow of Hailey and Bellevue treatment plants returns 2 cfs annually (1,450 af/y). The 660 af/y consumed by residents of these municipalities is 0.002 percent of the total water budget (356,000 af/y) term for the entire Lower Valley.

Lower Valley Water Use in Rural Sectors – For all practical purposes, domestic consumptive water use in rural sectors of the Lower Valley is considered negligible; consumptive water use for non-domestic purposes is another matter. This 255 square miles area supports a blend of natural vegetation and cultivated cropland.

About 65 percent of the region are the 106,000 acres of natural vegetation of range grass and brush which consumes 160,000 af of water each year through evapotranspiration. In the Lower Valley about 95 percent of this land is brush and range grass while the remainder is forested.

Within the Lower Valley is the 90 square mile---57,000 acre---region designated as the MODFLOW study site. A sizeable portion of this land is considered "marginal" and due to location or soil properties supports no marketable crops. Marginal land is usually found along foothill boundaries or in the riparion region of the Big Wood River.

In short, about 40 percent (23,000 acres) of the land in the MODFLOW study site is not cultivated.

With respect to the remaining 60 percent of the land in the study site, not all of the 34,000 "cultivated" acres are used for irrigation growing. Homes, outbuildings, roads, barnyards, landscape, etc. are considered "cultivated acres" even though they are not planted with irrigation crops. In actuality, only about 30,000 acres in the MODFLOW study site are considered to be irrigated acres that raise crops such as alfalfa, small grains, seed potatoes, or pasture.

Shifting our focus to how these acres are irrigated we find 47 percent is watered by surface canals and 53 percent from ground water or subirrigated pasture. Currently, three-quarters of irrigation application is through pressured sprinklers. Water consumed (ET) by crops grown in the MODFLOW study site was set at 107,000 af for the reference year. Adding ET values for natural vegetation with those for irrigated crops produces a consumed water estimate for the entire Lower Valley of 267,000 acre feet.[47]

Selected aspects of the Lower Valley water picture have remained somewhat constant such as the growing season, beginning in early April and ending in late October. Other aspects have changed over time such as croppage, number of acres under irrigation, and the method of irrigation. Table 11 presents a point to point comparison (1973,1993) for crop distribution. Note that these figures may not are for two points in time and taken from non-identical areas thus a review of land use data would be needed to confirm the magnitude of these changes. Perhaps the largest difference arises with the statistics on adoption of sprinkler irrigation. In 1975, 13 percent of the irrigated acreage used sprinkler techniques while in 1993 this increased to 74 percent.

Lower Valley Water Use: Summary

Irrigated agriculture is far and away the largest single consumer of water in the watershed. Several important factors influence the relationship between consumptive water use in the Lower Valley and its effect on Silver Creek. The amount of water diverted from the Big Wood River for irrigation has decreased somewhat in the past 25

Table 11. Changes in Croppage for Bellevue Triangle (1975 and 1995)

CROP	**1973** **(%)**	**1995** **(%)**
Pasture	40.5	42
Alfalfa	30	19
Barley	22	31
Wheat	2.6	1.0
Potatoes	0.2	4.0
Oats	1.6	2.0
Canola	0.0	1.0
Phreatophytes	3.1	0.0
Total	**100 %**	**100 %**

years, but just how much remains unclear. IDWR records (1928-1999) for the four "indicator" canals (District 45, Glendale, Baseline, and Blacks Ditch) suggest a decrease since the mid 1970s (Figure 8). Assuming precipitation has remained relatively constant, no one is exactly sure whether this decline is attributable to better irrigation efficiencies, changes in croppage, or reduction in acres under cultivation. In all likelihood, the reduction is due to all these factors. On the whole, it is believed that about 10,000 af/y less was diverted out of the Big Wood River in 1993 than in 1975 but this is a point to point comparison and may not constitute a trend.

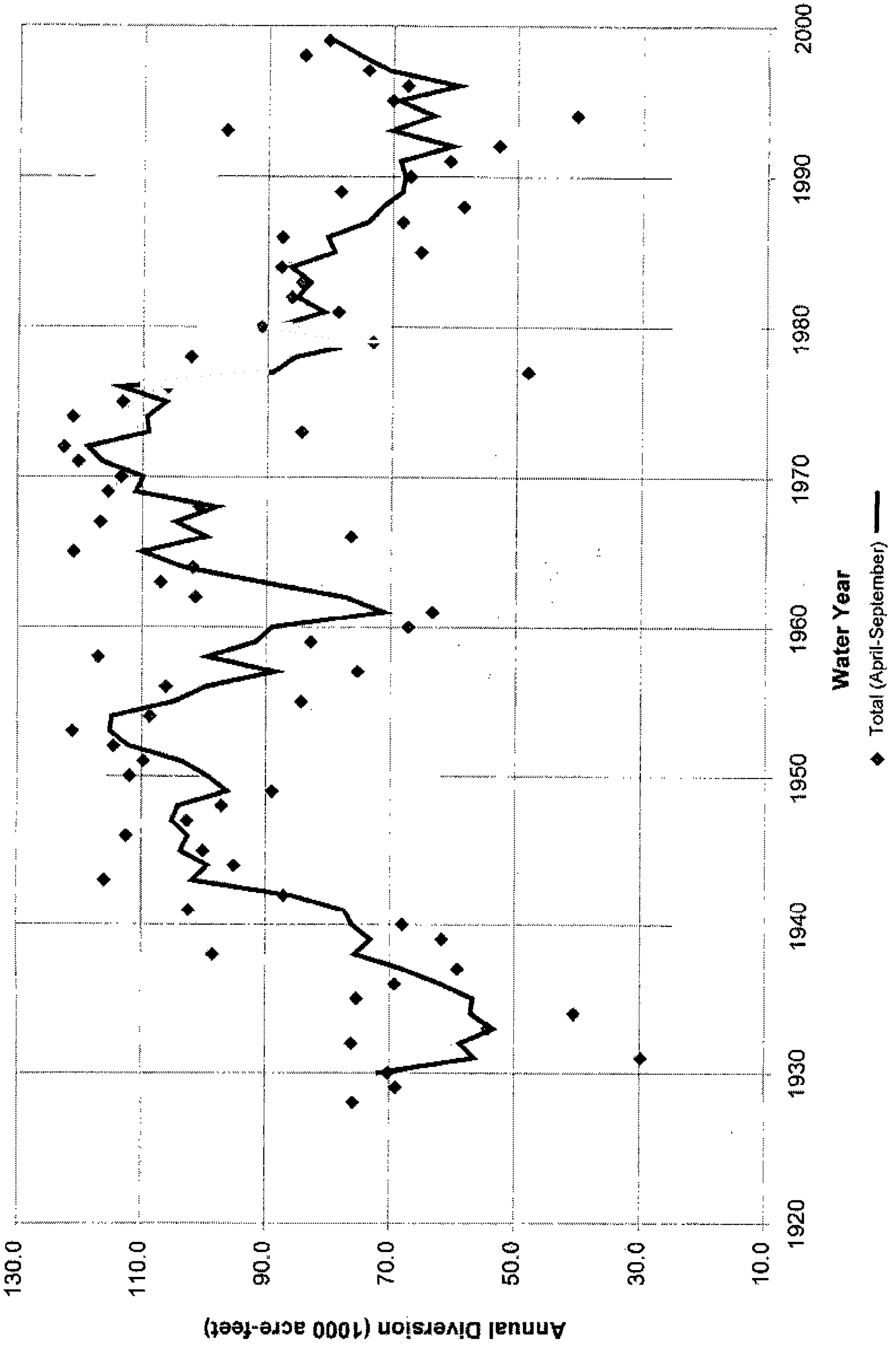
Phase II suggests any drop in surface irrigation diversion from the Big Wood River may also be due to an increasing tendency of farmers to use ground water as a primary rather than a supplemental source of irrigation water. This phenomenon is attributed to several factors. First, sprinkler systems are more easily pressurized from wells than by canal fed ponds. The use of canal water for sprinkler irrigation means the grower must first build a pond, the very act of which introduces its own problems. In wet seasons ponds can flood and drain onto a neighbor's land and in dry seasons there is no guarantee enough canal water can be supplied to keep the pond filled. Lastly, ponds evaporate standing water while ground water remains in the aquifer. It is true irrigators pay energy costs to lift ground water to sprinklers but many farmers remain convinced this cost is overcome by the convenience and dependability of ground water.

Perhaps the best way to grasp the big picture of water consumption in Bellevue region is to calculate water consumption per average acre. If 188,000 acre feet of water is spread over 30,000 acres this means each acre receives 6 acre feet of water. From standard tables it can then be estimated about 3.4 acre feet will be consumed by crop ET and 2.6 acre feet per acre return to the water resources system.

Rates of consumptive use for the Bellevue Triangle are in line with other amounts around the state. Rates of water use by Idaho farmers have remained constant since the early 1990s. In 1998, Idaho farmers used 6 million acre feet of water to irrigate slightly over 3 million acres or 2 af per acre. Idaho presently ranks third in the United States for water consumed and fifth for total acres irrigated.[48] Comparing state with local usage isn't easy because higher altitude at the study site means differences in crops and growing seasons.

The key to understanding the water resources system of the Lower Valley in general and Silver Creek in particular centers upon the role played by human intervention. The partially understood partially unanswered question remains: "to what extent are flows in Silver Creek driven by natural conditions---climatology and underflow---and to what extent are they driven by irrigation diversions?" What we do know are the basic relationships such as the fact that flows in Silver Creek rise and fall in proportion to flows in the Big Wood River, which are themselves linked to precipitation. It is also known that when river volume is high so are irrigation diversions. But the numerical problem remains. More specifically, what remains to be determined is the task of disentangling the precise relationship between Silver Creek's flow on one hand and precipitation, irrigation diversions, seepage and underflow on the other hand. This is a question where research will continue beyond the completion of ***Phase II***.

Figure 8. Big Wood River Diversions Above Magic Reservoir 1928 - 1998



WATER BUDGET

The term **water budget** refers to a concept developed by water scientists to help them understand the overall water system of the area they are studying. Sometimes this tool is called a "water balance," other times it is referred to as a "hydrologic budget" (or balance). Underlying this concept is the assumption there is a fixed amount of water in the world. In other words, while water may change location (from oceans to rivers to glaciers) or alter its state (from a gas, to liquid or solid) but there remains a fixed number of water molecules on earth. One estimate has set the world water balance---or hydrologic cycle---as being 3.89×10^{14} gallons (1.18 trillion acre feet) of water.[49] Each day the sun boils up over one trillion tons of water vapor of which 40,000 billion gallons drift over the conterminous United States; from these clouds only 10 percent, or 4,200 billion gallons, will fall as precipitation to begin the journey back to the seas.

In the pages to follow, this *Summary Report* constructs water budgets for the entire watershed, Upper and Lower Valleys, and the study site. Once again, to the point of tedium, the reader is warned that when reporting the magnitude of such statistics it is easy to give an impression of exactitude that may not exist. To minimize possible distortion, water budget statistics reported in text, figures, and tables are rounded up and stated in three significant digits. The water "pictures" to follow are developed using the conditions measured during the reference year 1993-94 and in some cases from average annual records.

Water Budget for Big Wood River Watershed

The entire Big Wood River watershed is thought to be 881 square miles (564,000 acres). For purposes of analysis, this region has been subdivided into 28 drainages contributing water from the surrounding mountains; 21 of the subwatersheds make up the Upper Valley, the remaining 7 comprise the Lower Valley (Figure 3).[50] Precipitation falling inside this domain becomes part of the water resources system of the Big Wood River, rain and snow falling outside its border contributes to the Salmon, Big Lost, and

Boise River drainages. Mean annual precipitation for the Big Wood River watershed is judged to be 26 inches per unit of surface area or about 1,330,000 acre feet each year.

Both human and non-human demands are placed upon moisture the moment it enters the watershed. Ultimately, these demands will consume about three-quarters of annual precipitation while the remaining quarter will pass through the system. Water withdrawn from the watershed totals around 985,000 af/y: 98 percent by evapotranspiration of forest, range, crops and landscape and 2 percent by municipalities.[51] The water passing through totals about 343,000 acre feet in the form of surface or subsurface flows. Broken down for the 1993-94 reference year we find: 91,100 as surface flows Silver Creek; 223,000 af from the Big Wood River at Stanton Crossing; and 29,300 af as ground water underflow at Picabo. These statistics---using the 1993-94 reference data---are summarized in Table 12 and illustrated in Figure 9 for the entire watershed.[52]

Table 12. Water Budget for Big Wood River Watershed

INFLOW (annual acre feet)		**OUTFLOW (annual acre feet)**	
Precipitation	1,330,000	Silver Creek (Sportsman's Landing)	91,100
		Big Wood River (Stanton Crossing)	223,000
		Ground Water Underflow at Picabo	29,300
		ET (forest, range, crops, landscape)	985,000
		Municipalities	1,960
Total Water In	**1,330,000**	**Total Water Out (Yield = 343,000)**	**1,330,000**

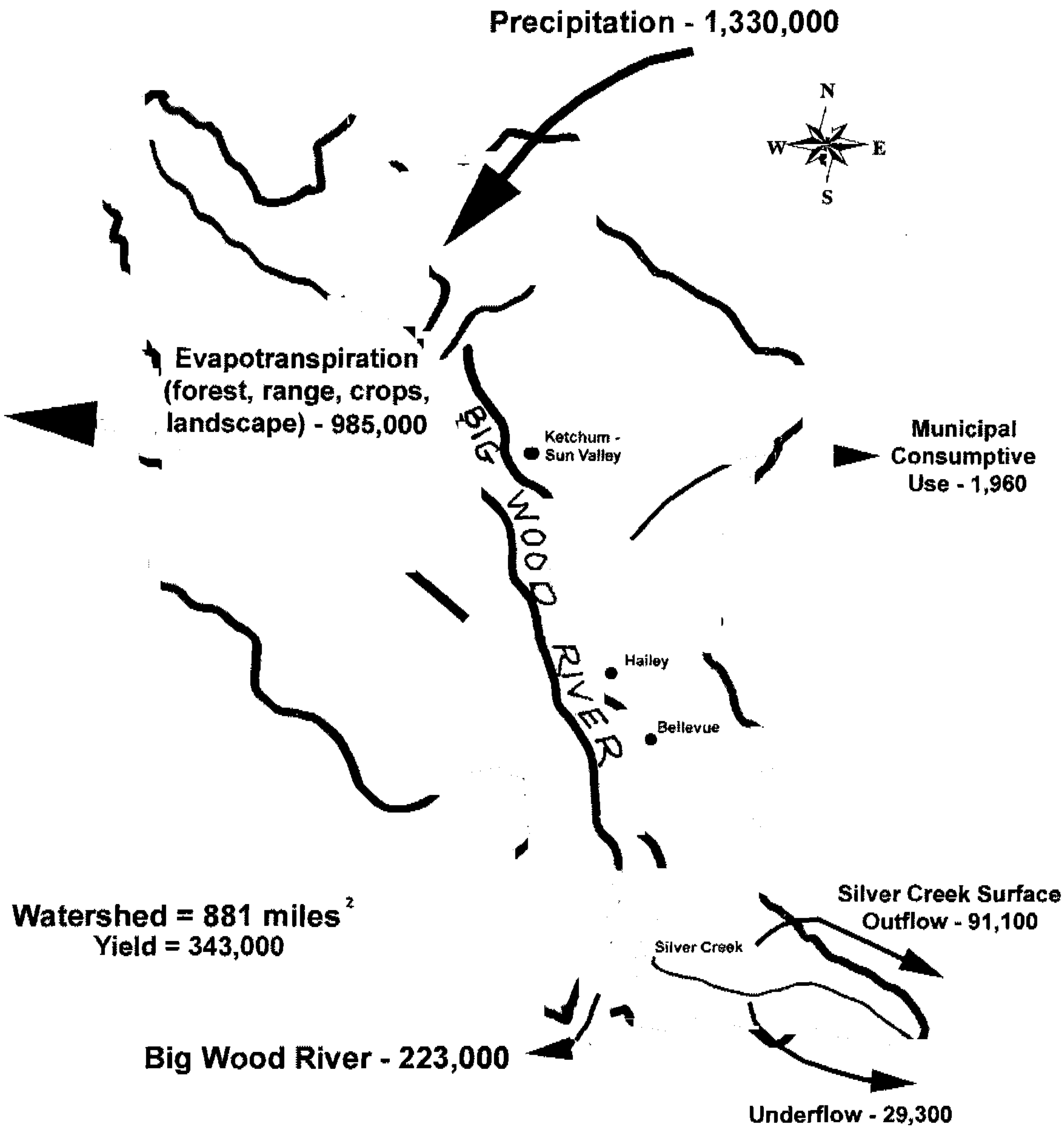


Figure 9. Conceptual Water Budget of Big Wood River Watershed (in Acre Feet)

Water Budget for Upper Wood River Valley – A water budget for the Upper Wood Valley is given in Table 13 and described in Figure 10. The areal extent of the Upper Valley covers 626 square miles and onto these 401,000 acres fall an average annual 1,110,000 acre feet of precipitation. Natural vegetation consume 699,000 af and an additional 17,000 af are taken for irrigation of crops and landscape. The municipalities of Ketchum, Sun Valley, and part of Hailey take an additional 1,300 acre feet (see Endnote 52). Upper Valley inflow exceeds the water extracted resulting in a positive outflow or "yield" to the Lower Valley. This *Summary* places Upper Valley yield at 393,000 acre feet for the reference year, 34,800 af of underflow and 358,000 af from river surface flow. The concept of yield is complicated and variation exists in efforts to estimate Upper Valley yield.[53]

Table 13. Water Budget for Upper Big Wood River Watershed

INFLOW (annual acre feet)		**OUTFLOW (annual acre feet)**	
Precipitation	1,110,000	ET from Natural Vegetation	699,000
		ET from Crops and Landscape	17,000
		Municipalities Consumed Water	1,300
Total Inflow	**1,110,000**	**Total Outflow (Yield = 393,000)**	**717,000**

Water Budget for Lower Wood River Valley - Boundaries of the 7 subwatersheds define the Lower Valley watershed and its water budget is summarized by Table 14 and illustrated by Figure 10. Inflow to this 255 square miles (163,000 acres) during the 1993-94 reference year came from three primary sources: (1) precipitation (219,000 af); (2) surface flow (358,000 af); and (3) ground water underflow from the Upper Valley (34,800 af). The sum of these inflows produced a total of 612,000 af for the Lower Valley that year.

Looking at outflows for the reference period, part of the Lower Valley's water exits as surface flow either through the Big Wood River at Stanton Crossing (223,000 af) or through Silver Creek at Picabo (91,100 af). Additional subsurface flows of 29,300 leave the basin as underflow near Picabo. Evapotranspiration of the Lower Valley's naturally vegetated portion removes 161,000 af while its cultivated acreage consumed another 107,000 acre feet. Lastly, municipalities consumed 660 af bringing the water balance for the Lower Valley to 612,000 acre feet. Exiting outflow (or yield) is thought be total 343,000 af for 1993-94.

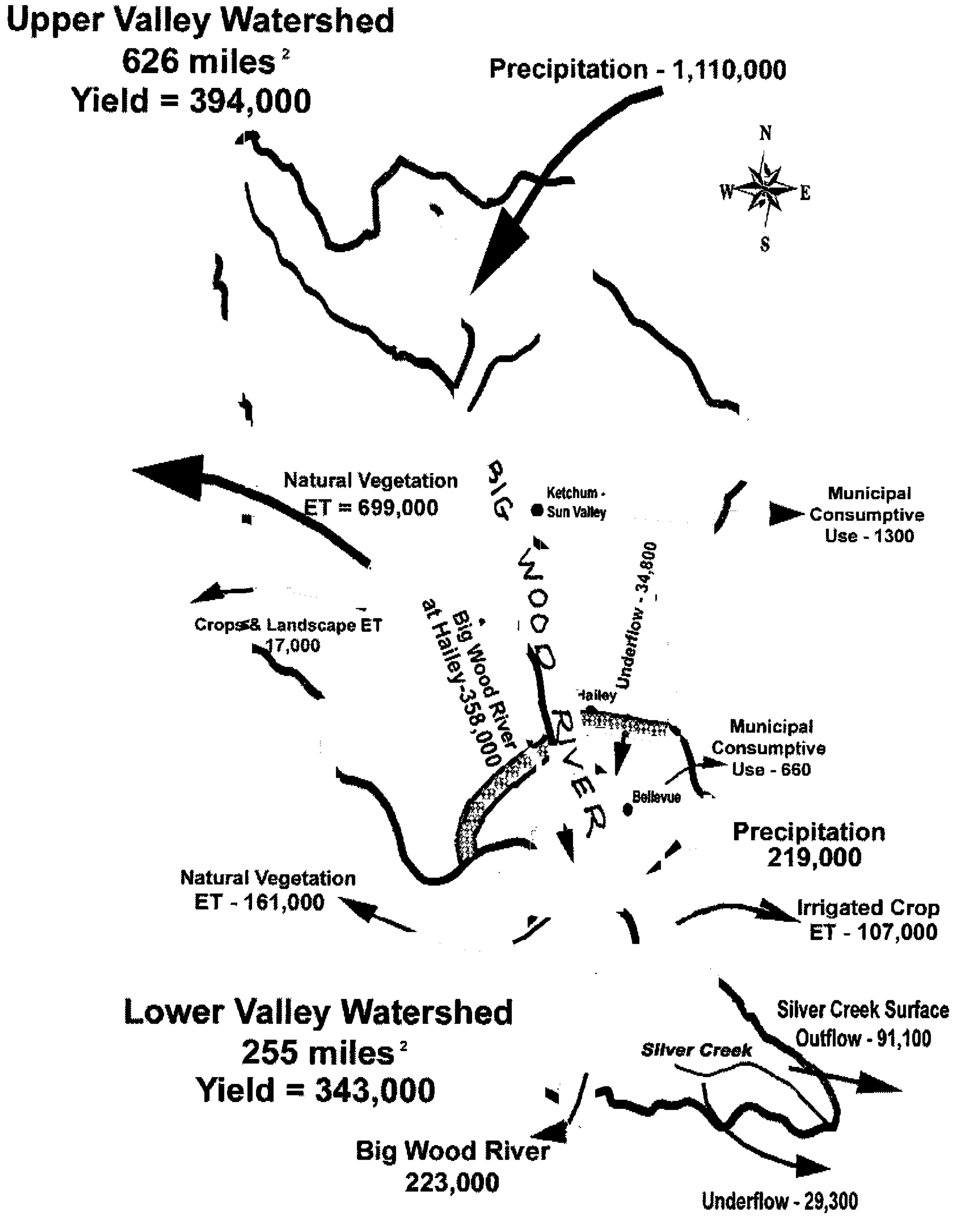


Figure 10. Conceptual Water Budget of Upper & Lower Big Wood River Watersheds (Acre feet)

Table 14. Water Budget for Lower Big Wood River Valley

INFLOW (annual acre feet)		**OUTFLOW (annual acre feet)**	
Underflow, Upper Valley	34,800	Underflow at Picabo	29,300
Big Wood River	358,000	Big Wood River	223,000
Precipitation	219,000	Silver Creek	91,100
		ET Natural Vegetation	161,000
		ET Irrigated Crops	107,000
		Municipalities	660
Total Inflow	**612,000**	**Total Outflow (Yield =343,000)**	**612,000**

Water Budget for MODFLOW Study Site – Both ***Phase I*** and ***Phase II*** formulated water budgets for the gridded areas. ***Phase I***'s budget stipulated more water left the grid area (219,000 af/y) than entered it (206,000 af/y) thus producing a water deficit.[54] This deficit, explains ***Phase I***, is associated with changes in storage, falling water tables and variations in "other components" in computing the budget (Table 15).

Table 15. *Phase I* Water Budget for MODFLOW Study Site

INFLOW (acre feet per year)		**OUTFLOW (acre feet per year)**	
Irrigation Diversions	92,240	Silver Creek Discharge	89,700
Seepage from Big Wood River	22,400	Ground water Underflow, Picabo	11,800
Underflow from Upper Valley	40,000	Spring Flow to Big Wood River	50,900
Precipitation	51,700	Evapotranspiration	66,500
Total Recharge to Study Site	**206,000**	**Total Discharge from Study Site**	**219,000**

Phase II also developed a water budget, albeit in more detail and with some revised approximations as presented in Table 16 and illustrated in Figure 11.[55] For the 1993-94 reference year, ***Phase II*** reported inflow from Big Wood River surface diversions to be 99,700 af and also introduced a pit recharge term of 1,400 af. Two other recharge terms deserve special attention: ground water irrigation and Silver Creek diversions. These terms are designated as both inflow and outflow because the water lost from these activities was incorporated into ET estimate. Altogether, ***Phase II*** placed water moving through the system to be somewhere between 355,000 to 357,000 acre feet during the reference year.

Table 16. *Phase II* Ground Water Budget for MODFLOW Study Site

INFLOW (annual acre feet)		OUTFLOW (annual acre feet)	
Big Wood River Diversions	99,700	Big Wood River Springs	38,300
Precipitation	51,300	Evapotranspiration	107,000
Groundwater Irrigation	52,000	Ground Water Irrigation	52,000
Silver Creek Diversions	36,500	Silver Creek Diversions	36,500
Underflow at Hailey	34,800	Underflow at Priest Road	29,300
Municipal Spring & GW	2,800	Municipal Groundwater	1,400
Big Wood River Seepage	79,200	Silver Creek Spring Outflow	91,100
Total Inflow	**357,700**	**(Yield = 120,000) Total Outflow**	**355,700**

While many of the statistics presented in this *Summary Report* are the same as those given in ***Phase II***'s water budget, they are sometimes presented in a different fashion. The logic behind the decision to present data in this manner is to provide the reader with a view of water movement not only between regions but within regions. ***Phase II***'s water budget illustration provides a look at intra-watershed transfers. Of particular interest is the important role played by surface diversions from the Big Wood River---the largest single source of water for Silver Creek's recharge zone. In other words, close to 100,000 af, or 28 percent, of inflow came from the Big Wood River. All told, ***Phase II*** set the amount of water moving through the MODFLOW study site during the study year to be about 358,000 acre feet (see Table 16, Figure 11).

The five water budgets presented above describe a complex water resources system at work in the Big Wood River watershed. These figures are given in the aggregate and should be tempered with the awareness they represent estimates made, for the most part, from a single year. It is true the relationships between water budget items

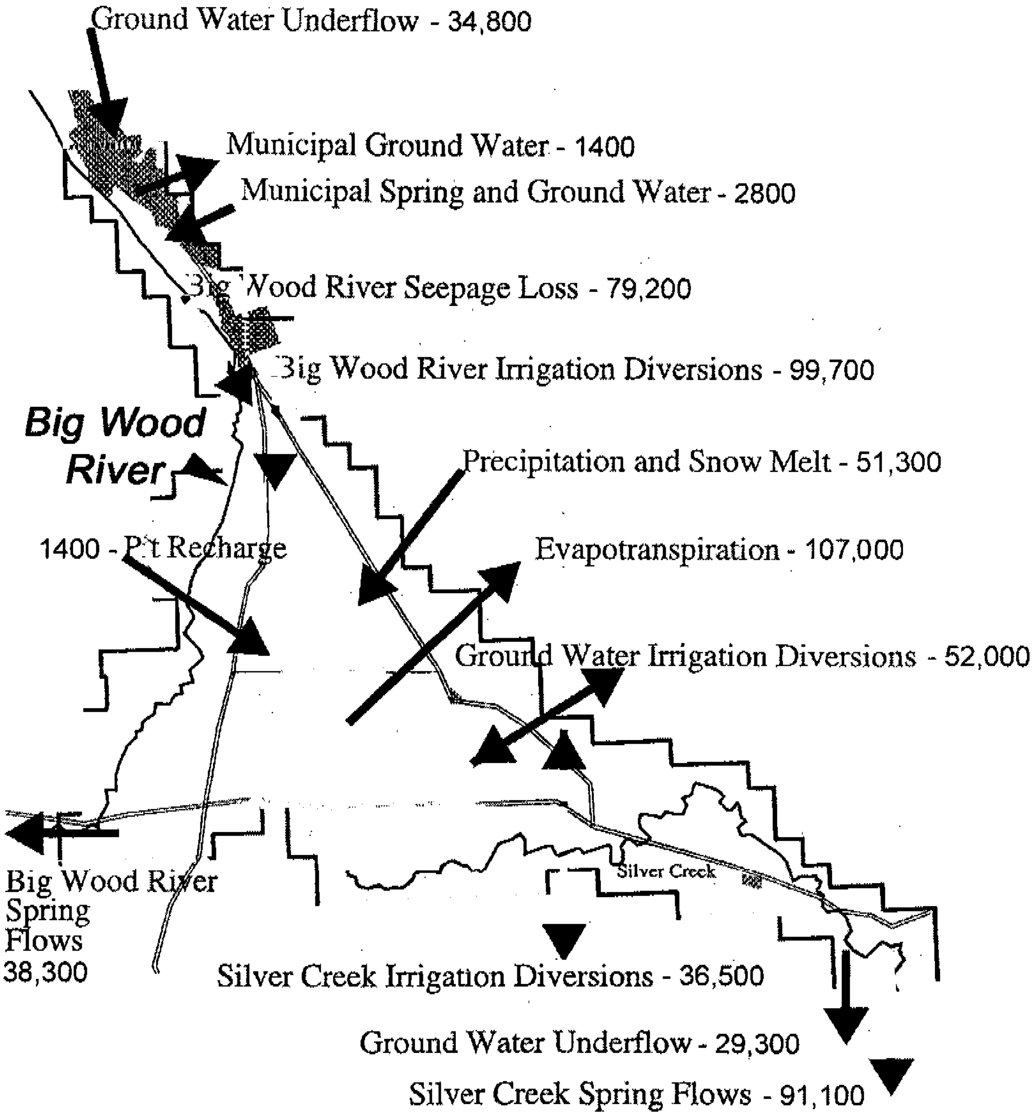


Figure 11. Conceptual Water Budget of MODFLOW Study Site (Acre Feet)

are more durable even though the annual measurements may vary. In any event, without deeper verification of both data and connectivity, prudence in usage is suggested.

FIVE SCENARIOS SIMULATED FROM MODFLOW

One beneficial aspect of MODFLOW is its ability to simulate conditions and project answers to "what if" questions. Specific interrogatives were formulated to represent five scenarios:

- A pre-irrigation scenario simulating water tables and spring flows prior to 1860
- Impact of removing selected wells upon adjacent irrigated lands and spring flows
- The effect of creating a combined waste water treatment facility using disposal fields in the northern part of the study site upon water Big Wood River & Silver Creek.
- Net effect of using excess Big Wood River flows upon Silver Creek
- Impact of using irrigation diversions for artificial recharge Silver Creek

Scenario 1: Simulation of Aboriginal/Pre-irrigation Time Period

Scenario 1 asked MODFLOW to go back in time---approximately 1860---and estimate flows in Silver Creek and the Big Wood River prior to the introduction of irrigation diversions. Guiding this inquiry was the desire to have a better understanding of Silver Creek in its "natural" state; *viz.* - before the introduction of human activities.

- Scenario 1 is important for several reasons. One of its most significant objectives is to explore how much of Silver Creek's flow regime is a function of surface irrigation water applied to its recharge zone and how much is explained by factors not directly regulated by human intervention (i.e. precipitation, seepage, Upper Valley underflow). Of corollary importance is the identification of altered to flows in the Big Wood River as a result of human involvement. Trying to unravel these connections may not appear daunting at first, but complexity soon surfaces. For example:
- How is seepage affected by leaving more water in the Big Wood River?
- How much land existed in a marshy condition prior to 1860?
- What ET values best represent crops replaced by foliage?
- Was underflow from the Upper Valley greater before development?

To simulate aboriginal conditions, the model was first programmed to accept precipitation and underflow values used in the reference scenario. Next, estimates of consumptive use (ET) for cropland were replaced with ET values for range and brush (northern part) and marshy swamp (to the south). This meant researchers assumed rangeland existed in the northern section of the triangle from an east-west line drawn through the community of Gannett. The area south of Gannett (and bounded by Highway 75 to the west, Gannett Road to the East and Timmerman/Picabo Hills to the south) was specified as being marshy swampland. Finally, the effect of irrigation wells and surface diversions was removed.[56]

Given these substitutions, the model responded by lowering the flow of feeder springs to one third of the reference scenario's values. Thus, spring flows from the aquifer into the Big Wood River would decrease by 40 cfs while simulated spring flows to Silver Creek fell by 120 cfs. At no time did Silver Creek cease to flow entirely.

What about water tables? Above Baseline Road, the simulation indicated water levels could fall as much as 20 feet while wells located closer to the center of the grid declined an average of 10 feet. Since no water was being taken out of the Big Wood River for irrigation diversion, the model envisioned a 10 foot rise in well levels in the southwestern portion of the study due to increased seepage from the river itself.

Underflow at Priest Road was likewise affected. MODFLOW projected a decline somewhere in the range of 14 percent compared to the reference scenario, or in other figures a decline of 4,000 af/y from 29,300 af to 25,300 af.

Since the implications of this scenario are profound, it is essential to introduce additional perspectives. As with all computer simulations, validity rests upon the assumptions introduced by researchers. ***Phase II***, itself, has urged caution with respect to interpreting the results of the simulation too literally because the degree of hydrologic stress between the reference and the pre-irrigation scenario is large. Meaning, there is a chance the model is being asked to provide forecasts in an area where it is stretching the "reasonableness" of physical relations submitted to it. For example, a critical assumption adopted in the pre-irrigation scenario rests upon the extent of marshland. Lacking information, IWRRI has to estimate the extent of marshland in the recharge zone during the 19th century. Based upon anecdotal evidence, considered opinion from government agricultural agents, water officials, and--in the case of ET coefficients---accepted scientific tables, an areal amount of marshland was determined.

The marsh portion of the recharge zone was set at about 6,400 acres (10 square miles) with an ET value of 36 inches.[57] If these assumptions are accurate, then Silver Creek flows were substantially lower as predicted. If any one of the assumptions are inaccurate then the scenario will be skewed. For example, if marshland was overestimated then the decrease in Silver Creek spring flow would likewise be inflated. Conversely, if marshland was underestimated the model response in spring flow decline is likewise underestimated. The same relationship holds for assignment of ET values for marshland. IWRRI researchers believe their approximation provides the best fit of conditions. In fact, if anything, they believe, ET might be underestimated due to the marshland's proximity to arid wind and lands which are capable of producing a "clothesline" effect—a phenomenon which can easily double ET. The longer water pools in the marshland the more it is evaporated by warm winds and transpired by aquatic plants. The net effect of an extensive marshland in Silver Creek's recharge zone is that it would leave less water for deep percolation, hence less water being discharged by the springs driving the stream.

Unraveling the inter-connectedness of these factors poses big questions. What resources are most likely to be affected by changes in Silver Creek flows? How far does the situation have to deteriorate before a critical condition is produced in Silver Creek? What, in fact, do we mean by "critical" conditions and who shall define these parameters? Perhaps a corollary question asks if a "compromise point" can be identified where both habitat and humans flourish? How about the Big Wood River; does the context of the issue bring into question the effect irrigation diversions have had upon habitat below Glendale Bridge? As with most all computer simulation, Scenario 1 has clearly raised more questions than answers. In order to evaluate these outcomes it is very likely other simulations are needed, ones exploring a range of values for input terms and capable of shedding light upon the relative tradeoffs which can be accepted.

Scenario 2: Selective Well Removal

A second simulation sought to assess what would happen to water levels and spring flows when selected wells (and their associated irrigation areas) were taken out of production. Six wells were chosen for this experiment located near the Conservancy manager's house on the Silver Creek Preserve.[58] To run this simulation, water consumptive values were assigned for irrigated crops associated with the removed wells and substituted with known values for the appropriate natural vegetation.

Results from the well removal scenario indicated Silver Creek flow would begin to increase gradually in early June and build to a maximum of 4.5 additional cfs in early September. No significant change in spring discharge into the Big Wood River were predicted.

Scenario 3: Waste Water Treatment with Disposal Fields

A third simulation examined the effect on water tables and discharge springs of spreading effluent from municipal waste water treatment plants spread over disposal fields in the northern part of the recharge zone. In actuality, Scenario 3 is two separate simulations: (1) what would happen if Bellevue's present treatment facility at Poverty Flats is expanded; and (2) what would happen if a new disposal facility is constructed at a site south of Bellevue near Gannett? The general conclusion drawn from the results of these simulations was "not much." MODFLOW forecast inconsequential changes in underflow, water tables, or spring discharge to the river or Silver Creek.[59] The reason for relative absence of impact is because municipal sewage effluent is small (5.0 cfs) compared to the magnitude of water volume in the valley. The flow of the Big Wood River at Hailey would be reduced by an amount equal to the effluent which otherwise would go into the river. Water levels in the study site would fall slightly averaging less than 0.03 cfs due to a reduction in river flow which caused a reduction in the seepage. Effluent from Bellevue or Hailey does not figure into the picture since these waters are already taken into consideration by MODFLOW as recharge terms.

Scenario 4: Artificial Recharge Using Excess Big Wood River Flows

The fourth scenario also involved two separate sub-simulations. In these instances, MODFLOW was programmed to project the effect of placing excess flood flows from the Big Wood River onto the Silver Creek recharge zone. To simulate this event, the model removed excess flows from the Big Wood River and channeled them via existing canals into six hypothetical pits located in the grid area. Both sub-simulations shared similar assumptions about flood flows such as what constitutes an "excess" flow, duration and timing of excess water, and estimated water available.[60] Basically a flood flow was designated to be any amount of water passing Stanton Crossing (between October through April) exceeding 75 percent of Magic Reservoir's capacity.

In the first sub-simulation, a 56 year period (1916-1996) was examined to determine the frequency and volume of excess river flows. This analysis determined about 29,000 acre feet would be available for 52 percent of the time (generally the period of record indicated excess flows on the average of every other year). The second simulation asked what the result would be of a one-time diversion event assuming the maximum volume the system could carry. In other words, the distribution canal system, it was determined, has a peak capacity of 70,000 acre feet. This simulation asked what would be the effect of a one-time event of 70,000 acre feet over a longer time span.

The results of the first sub-simulation (29,000 acre feet for one year) forecast an increase of 20 to 45 cfs (15% to 25%) in spring discharge to Silver Creek with the minimum increase occurring in March and the Maximum in June). The Big Wood River was predicted to gain 5 to 12 cfs while underflow at Priest Road increased by 600 acre feet. Water tables in the unconfined aquifer between Hailey and Glendale Bridge rose 15 feet, further down (near Baseline Road) water tables gained about 5 feet. Below this layer, in the confined aquifer, artesian water levels rose between 2 to 5 feet.

The second sub-simulation dumped a one-time shot of 70,000 acre feet into recharge pits located on the recharge zone between April 1 and June 30. The purpose of this scenario was to assess the temporal extent or how long would the effect of such an event last? The model predicted a maximum increase of 77 cfs in mid to late June for

Silver Creek and a maximum increase of 15 cfs for springs discharging back into the Big Wood River. What is interesting about this simulation is the flow declines rapidly for Silver Creek after its June peak yet its net effect takes almost three years to dissipate. In fact, a year later stream flows are still up about 30 additional cfs and even in the second year some increased spring is present although greatly diminished. In the Big Wood River the discharge springs decreased at a more gradual rate than did Silver Creek.

The overall implication from the second simulation is the aquifer appears to be demonstrating a limited storativity capability and excess flows introduced in one year can still be noticed one or even two years after the event.

Scenario 5: Artificial Recharge Using Irrigation Diversions

The final scenario also had two sub-simulations. Both computer runs sought to evaluate the effect of recharge water on water tables and spring flows by asking MODLFLOW to project what would happen if 10 cfs of water were place in five selected recharge pits.

The first sub-simulation shifted 10 cfs of water normally used for irrigating crops to pit recharge. This simulation was accomplished by removing ET and deep percolation associated with irrigated crops and exchanging these values with similar values for rangeland.[61] MODFLOW indicated water tables would increase only a maximum of 0.4 feet and observed no significant underflow difference at Priest Road. Flows in Silver Creek rose 3.2 cfs during late August and showed an increase of 1.5 cfs for the remainder of the year.

The second sub-simulation was similar except it redirected 10 cfs of water to recharge pits brought in from outside the study site. Here, 2 cfs were allocated to each of 5 recharge pits from mid April until the end of November. Water tables generally increased with the largest single rise being 1 foot (only at one location). Underflow at Priest Road increased 200 acre feet and Silver Creek flows rose 3 cfs in early April to a maximum increase of 5 cfs in late November and then returned to a constant increased level of 3 cfs. For the Big Wood River, the model simulated a maximum increase of 3.3

cfs at the end of August, with a beginning and ending increased flow of 1.2 cfs for the period.

Summary of MODFLOW Scenarios – The simulations run by MODFLOW were designed to explore selected aspects of the aquifer. By no means did the scenarios answer the complex questions concerning alternative uses of the water resources system but they do reveal the potential of MODFLOW. With the model now calibrated, it can be extended to probe further into these complicated issues.

Several findings stand out above the rest. The crucial connection between water diverted for irrigation and the flow of Silver Creek is readily apparent in the pre-development scenario. The same is true for underflow. While the other simulations indicate small or inconsequential changes in underflow, the pre-irrigation scenario simulated told us there is definitely a strong correlation between surface diversions for irrigation and surface/under flow in Silver Creek. Even though the exact numerical relationship between irrigation diversions and surface/under flow may not be known at this point we do understand the importance of this connectivity in its relative sense.

Another fascinating piece of the puzzle has to do with the possibilities raised by artificial recharge. The largest increased flow to Silver Creek happened when excess river flows are introduced to the study site recharge zone. When a large flood flow is introduced the effect can be observed a year or two later which gives us some indication of the aquifer's storage capacity. Finally, the scenarios indicate the effort to place flows from either effluent or flood events into recharge pits has limited merit and is of secondary importance.

PART III

CONCLUSIONS & FREQUENTLY ASKED QUESTIONS

Since summarizing sections are already presented in both ***Phase I*** and ***Phase II*** as well as in sections of this report, what follows is in a different format. This concluding section sets out to anticipate and answer frequently asked questions about the water resources of the Wood River Valley and the Bellevue Triangle and.

CAN WE TRUST THE NUMBERS AND FINDINGS?

Science is a distinctly human activity and as such shares the strengths and weaknesses of people's abilities. Concepts in physical sciences---as hydrology and geohydrology---are only as good as the data collected to support the research. In this case---as ***Phase II*** is careful to stress---potential error associated with its data gathering processes is always present. Estimates of seepage, for example, vary considerably from values in other reports as well as between ***Phase I*** and ***Phase II***. Records of ground water pumpage were acquired from well owner's personal observations and memory and can be considered only "fair" at best. Statistics on surface water irrigation diversions are thought to be "good" since they are taken from Watermaster daily records as were estimates of consumptive use derived by using accepted methods in the profession. Measures of underflow had to be computed from related statistics and any error in those forecasts would be compounded in underflow calculations. Efforts to set underflow at Hailey, for example, appear to correlate with the findings of some other inquiries but even then variation exists between these other studies. Measurements of flow in Silver Creek were vulnerable due to USGS' decision to cease gauging altogether in 1963 only to resume measuring 11 years later by relocating the gage to an entirely new site. Even river measurements taken at Stanton Crossing were difficult due to wandering stream channels and sediment deposition.

Given these limitations what, then, can we trust and what should be viewed with suspicion? Physical sciences tend to be weakest at the extremes: they are not very good when numbers are either very large or very small. The limits are clearly being pushed when reporting figures such as the average annual precipitation for the Big Wood River Watershed of 1,331,040 acre feet or the coefficient for confined storage at 0.000001. The same can be said for the temporal dimension; when science tries to predict into the future or postdict into the past, the further the reach the more suspect the results On the other hand, science is much better at measuring and understanding the mid-range, the close at hand rather than the distant.

Taken in this light we can trust the findings of this study in two primary ways. First, look at the numbers in a <u>relative</u> rather than an absolute sense. When the study says something in one area is 400,000 af/y while only 200,00 af/y in another area, don't take this to mean one is twice the size as the other but instead one is larger than the other. The corollary to this reservation is connected to discussing numbers in terms of data obtained during the reference year of 1993-94. The absence of consistent, long-term records as well as financial constraints disallowed acquisition of an extensive database. Therefore many statistics cited are a function of conditions prevalent during the reference period rather than long term averages.

Second, findings pushing conditions into the future or into the past should be used with caution. The MODFLOW model is best at explaining the nature of the physical conditions of the aquifer in the Bellevue Triangle and it can be used to develop the "what if" scenarios. But the results of these simulations should not be accepted without critical assessment and evaluation in light of other known records and common sense. The development of the MODFLOW model can be best viewed as another step towards developing a solid information base for the water resources system of the Wood River Valley. The figures reported in ***Reports*** are the product of the best available technology we have. They may not be entirely accurate but they are---taken as a whole---reasonably close and stated in their proper relationship to one another. Like any human activity, however, it needs continual refinement, adjustment, and application to prove its worth in the long run.

Professional peer reviewers in Idaho and California were contracted to comment on ***Phase II.*** One reviewer stated the model appears to have been "…developed using generally accepted methods. A great deal of data was collected…calibration appears acceptable based on data provided in the report and the scenarios appear to have provided reasonable results." The second reviewer stated "The general model design is straightforward…I believe that the model as constructed provides a useful water management tool for water managers and users in the basin. Care should be taken to use the trends indicated by the model and not the absolute values." Each reviewer then went on to list specific areas of concern and suggestions for improvement. In one instance a lengthy conference call was held to clarify selected sections between two outside reviewers and the research staff. The S***ummary Report*** was also reviewed (The Nature Conservancy and IWRRI) for errors and omissions.

HOW MUCH WATER IS IN THE WOOD RIVER VALLEY?

Water is life in the Wood River Valley. If we had no snow or rain it is clear the communities in the valley would not exist. The watershed for the Big Wood River drainage is probably between 800 to 1,000 square miles and receives considerable precipitation in a normal year. Over one million acre feet of water fall annually over the basin. By a four to one ratio the lion's share of this moisture (1.1 million acre feet) is spread over the northern part of the watershed and not on the southern portion (219,000 acre feet.) Using Hailey as a measuring point, flows in the Big Wood River flow range between 320,000 af/y and 390,000 with something in the middle being "normal." The amount of ground water flowing through the valley is not known precisely, but at Hailey scientists think it varies between 30,000 af/y to perhaps as high as 60,000 af/y; agreement is more on the lower end than the higher end.

What is clear is that water leaves the drainage. In other words, we do not withdraw and consume more water from the system than enters the system. Surface water leaves the drainage from the Big Wood River and Silver Creek along with ground water exiting as underflow beneath Picabo. This "yield" could be as much as 350,000 af/y but more likely it is less.

In general terms, at least for the present, the water resources system for the Wood River Valley appears to be in a positive but delicate balance. Prolonged drought, changes in patterns of water consumption, or water policy such as the Snake River Basin Adjudication could tilt the scale towards greater scarcity.

A corollary question revolves around whether or not "there enough water for future development?" Even though this major question raises one of the leading issues in the West today it was not a direct focus of ***Reports.*** We cannot, therefore, expect to "tease" too much out of the study's findings but there are some facts for consideration. ***Phase II*** does develop a few coefficients and scales of comparison that can be used to assess tradeoffs in future building projects. It also explored selected aspects of rural buildout in the Upper Valley. While ***Phase II*** does not provide a definitive answer to the "is there enough water for future development" question, it does create a tool for investigating such problems analytically and comparatively. ***Phase II*** also reveals just how little consumptive use is associated with human activities in the Upper Valley compared to natural vegetation (2.6 percent) in contrast to the Lower Valley's (67 percent). It should be remember, however, that practically all of the water withdrawn in the Upper Valley is taken from ground water and not surface water.

Whether or not there is enough water for future development is a double-sided issue. On one side policy makers require knowledge about water resources to make choices with respect to parcel sizes, well moratoriums, density, infrastructure, and etc. On the other side, water scientists cannot project answers about water resources parameters without making assumptions about these same variables (i.e. parcel sizes, density, etc). Both activities have need of each other. The greater the cooperative collaboration between the two enterprises, science and policy, the more powerful a tool like MODFLOW becomes. The issue isn't whether or not growth will take place in the Wood River Valley, but rather what is the most optimal way to configure that growth. The chances of uncovering the best solutions rest on the extent to which science and planning, work together.

WHAT IS HAPPENING TO WATER TABLES?

Posing the question "what's happening to water tables" can only be answered against the backdrop of time. Not stipulating an exact time period confuses the issue and makes a valid answer impossible. For example, the answer to what is happening to water tables in this area over the past 200 years would be considerably different than an answer directed towards, say, the last decade. At first blush this insight seems so patently simplistic to verge on the absurd, but no small source of confusion and misunderstanding has resulted because of the absence of defining the time period.

No one really knows what water tables were like in this region even just 100 years ago. Better records exist for the Lower Valley than the Upper Valley but it is probably a safe guess to say water tables were just about the same then as they are today. On the other hand, water tables, at least in the Upper Valley, were probably different between the 1940s and 1960s than they were either today or last century. The reason for this is that irrigation diversions out of the river for crops tended to raise water tables especially on the west side of the Upper Valley. It was not uncommon for basements to flood on the northern edges of Hailey. As development took place the irrigation canals began to disappear and high water tables returned to closer proximity to the river. Today, residents in the Wood River Valley withdraw more water for domestic purposes than they did at the turn of the last century. But water diversion is not the whole story and the fact of the matter is that practically all water withdrawn for domestic household use is returned to the water resources system. In the Upper Valley about 1 percent of the total precipitation is "used" consumptively by human activities, in the Lower Valley is a different situation.

Agriculture is a major part of the water resources system for the Big Wood River watershed. Yet even in the Bellevue Triangle where well water extraction is prevalent during summer months, it is difficult to observe a long term drop in water tables. Water table changes take place seasonally and can show great variation depending upon locale and climatic conditions---some times as much as 20 feet or more. Looking at water tables since the 1970s, however, does not indicate large changes have taken place.

Reports analyzed information gathered from 18 observation wells taken in 1975 and in the 1993-94 reference year and concluded a general decrease of about 1 foot had taken place in the water table (unconfined) with slightly greater decreases in the artesian (confined) aquifers.

WHAT IS HAPPENING TO SILVER CREEK?

Silver Creek appears to be flowing between 120 cfs and 180 cfs annually. Historical stream flow records have been kept ever since the early 1920s by USGS. As pointed out several times, however, it is difficult to know just how to use this information considering record taking ceased in 1963 only to resume eleven years later at a different location meaning we have no continuous record for Silver Creek flows.

We do know there is a distinct seasonal variability within years. It is also fairly safe to assume there were increasing stream flows during the peak flood irrigation years which began right after World War II. This period was followed, however, with a marked drop beginning in the mid 1980s and lasting to the mid 1990s and since then flows have rebounded. Scientists are concerned about the connection between the irrigation diversions laid on Silver Creek's recharge zone and the flows in the stream channel. The problem, however, is to disentangle just what percent of the variation in Silver Creek's flows is explained by "un-natural" processes (irrigation diversions, percolation from un-lined canals, municipal recharge) and what part is explained by "natural" factors (precipitation, seepage from the river, ground water underflow).

No doubt a large percent of the stream flow variability occurring in Silver Creek is explained by variations in irrigation diversions from the Big Wood River. But other factors could also affect this connection such as underflow, seepage, or groundwater pumpage. It is for this reason that Scenario 1---simulating the conditions before non-native settlement---is an important one. If the assumptions in the simulation are valid then the connection between Silver Creek and surface diversions out of the Big Wood River are profound. Conversely, if the model was mis-specified in assumptions resulting in over (or under) estimation of 1860 conditions then other explanations will have to be identified and tested.

HOW GOOD IS WATER QUALITY IN THE WOOD RIVER VALLEY?

Water quality is an important consideration for the Wood River Valley. The focus of ***Reports***, however, was water quantity and water systems not water quality. Two major reasons underscore this decision. First, water quality analysis is a separate and major undertaking from ground water modeling. This type of investigation requires different training, equipment, and approach. Second, water quality is monitored frequently by other government institutions from federal, state, and local agencies. The United States Environmental Protection Agency requires the municipalities of Ketchum, Sun Valley, Hailey and Bellevue to engage in a systematic program of sampling and analysis. Coloform bacteria are monitored daily while water is sampled for other microbiological organisms weekly. Nitrates and asbestos or monitored annually with lead and copper testing done a minimum of every three years. Testing for 16 regulated and 7 unregulated synthetic organic compounds is conducted annually and is testing for 26 regulated and 30 unregulated volatile organic compounds. Radio nucleotide analysis for alpha and beta particles are also conducted every year. Copies of these reports are available from municipal water and sewer districts.

While Silver Creek is not used for drinking water, two recent water quality studies were undertaken by The Nature Conservancy. Between 1991 and 1994, Conservancy personnel took measurements at regular intervals for dissolved oxygen, water temperature, conductivity, turbidity, pH, nitrates, phosphates and ammonia as well as sediment depth and aquatic plant cover. All samples for nitrite, phosphorous, and ortho phosphates were below detection thresholds while nitrate exceeded EPA guidelines for drinking water in 1994. In 1998, The Nature Conservancy contracted with Dr. Lee Brown to prepare *PESTICIDES AND THE SILVER CREEK PRESERVE: An Assessment of the Feasibility and Necessity of Soil and Water Testing for Contaminants.* The results of both of these studies are available from The Nature Conservancy in Ketchum, Idaho.

WHERE TO FROM HERE?

Silver Creek is clearly a major resource for the Wood River Valley. It is important in an "extrinsic" sense in that it provides benefits for humans of an economic, recreational, aesthetic, and spiritual nature. But it is also important in an "intrinsic" way because it provides non-quantifiable benefits which have worth in and of themselves for the biotic community of the Preserve. As a result, it has been the intention of TNC all along to initiate steps to insure the work done on this study is not wasted. Now that the model is calibrated and developed its potential for usefulness in the Wood River Valley is quite strong.

The Nature Conservancy is taking steps to see the model is both housed in the valley and operated by trained individuals capable of making its full potential available to interested parties. One major contender for the physical location of MODFLOW is with the newly formed Conservation Education Center (CEC) located at the Environmental Resource Center in Ketchum. This group, with support from Idaho State University, is planning to warehouse state of the art software with respect to environmental issues including GIS (Geographic Information Systems) materials. Another possible alternative centers upon the key role played by agriculture in Silver Creek's recharge zone. Perhaps the formation of an Advisory Committee composed of representatives from adjacent landowners, farmers/ranchers, technical advisors, and county government. Such a group could explore alternatives and build necessary coalitions for problem solving and conflict resolution. Lastly, it is clear that despite the extensive effort undertaken in ***Phase I*** and ***Phase II*** unanswered questions remain and can only be addressed by establishing an improved system of monitoring and record keeping. The design and implementation of this network comport the next phase of the on-going effort to understand the region's water resources system. ***Phase I*** and ***Phase II*** provide the initial steps to obtain a systematic and scientific understanding of the watershed; where it goes from here is up to us.

APPENDICES

APPENDIX 1 – GLOSSARY

Acre-Feet – One acre foot of water is a measure of volume. One acre foot of water is the equivalent of one acre (43,560 square feet) of land with one foot of water (thus 43,560 cubic feet) upon it. This volume is equivalent to 325,828 gallons, or about the size of an Olympic swimming pool.

Artesian – It used to be the term "artesian" applied to either a very deep well or one that was free flowing at the surface. Neither of these views is technically correct. Artesian basically means any situation in which ground water under pressure rises above the level of the aquifer. Water that is in a confined aquifer (both above and below) will be under increased pressure the lower in drops in altitude. This pressure forces the water above the lower level much like a tube filled with water would come out of the lower end if you raised the other end over your head. If the lower end also happens to be above the ground surface then an artesian well is produced. (see aquifer).

Aquifer – The term "aquifer" is given to underground soil or rock through which ground water can easily move. If the aquifer has clear boundaries that limit water's movement (downward or sideways) it is said to be a "confined" aquifer. An unconfined aquifer, like a desert region, might ultimately have a bottom to its saturated zone but isn't hemmed in by rocks or mountains. An "aquiclude" is a saturated geologic unit that is incapable of transmitting significant quantities of water. Somewhere in-between is the "aquitard" that describes less water movement but generally not enough to be productive.

Frequently there can be layers of aquifers stacked upon each other like plates in a cupboard. The topmost aquifer might have no cap to it while ones below it are channeled or boundaried by impermeable layers. This is the case in the Wood River Valley. The uppermost aquifer is bounded to the East and West by rock formations of the mountains while the valley floor is hundreds if not thousands of feet of alluvium, or washed down debris from the mountains. As one moves further down valley aquitards appear separating the channels of subsurface water following gravity to the seas. A "perched" aquifer occurs when an unsaturated zone separates unconfined ground water from an underlying main body of ground water.

Biodiversity – "Biodiversity" is a term which has gained popularity over recent years and is a key element in conservation biology. It usually refers to the number of species---wildlife, plants, etc.---present in a given area and their ability to perpetuate themselves. In theory, species found in diverse locations with differing genetic characteristics are more likely to survive than species lacking genetic diversification. Some individuals have taken this principle a step further and asserted that biological diversity is instrumentally and intrinsically important to man. Conservation biologists, for example, have sought to demonstrate that mature, larger, and structurally complex ecosystems support a wide diversity of species and can thus absorb otherwise destabilizing environmental changes.

In 1976, the National Forest Management Act addressed biological diversity by requiring the U.S. Forest Service to "provide for diversity of plant and animal communities based on the suitability and capability of the specific land area in order to meet overall multiple use objectives." 16 U.S.C. 1604 (g) (3) (B).

Conservation Biology – The science of conservation biology has grown in direct proportion to the increasing rate and scale of extinction and habitat destruction. It is applied science designed to help policymakers and citizens understand better the consequences of alternative environmental actions. At the core of conservation biology is a recognition of "flux" or change provides a better model for understanding nature than to see it as orderly, steady state, and in "balance." Noted biologist Michale Soule states it is "...a new stage in the application of science to conservation problems, addresses the biology of species, communities, and ecosystems that are perturbed, either directly or indirectly, by human activities or other agents. Its goal is to provide principles and tools for preserving biological diversity."

Consumed Water – Hydrologists differentiate between water that is "consumed" versus "nonconsumed." Technically speaking, no water is wholly consumed but instead changed to one of three states: liquid, gaseous, or solid. R. L. Nace (1971) *UNESCO Tech. Papers Hydrol.* estimates total world water balance to be 3.85 X 10^6 gallons of water. When hydrologists speak of water being consumed in a watershed they refer to water not returned to surface or ground waters, generally this means water than has been evaporated or transpired (hence evapotranspiration). As defined in ***Reports***, "Consumptive use is that amount of water changed from a liquid or solid state into water vapor by evaporative processes." Consumed water, therefore, is equivalent to water lost by ET and not available to the adjacent ground or surface waters.

Non-consumptive uses of Upper Valley water do not deplete the basin's water supply (i.e. washing dishes, canoeing, fishing) while consumptive uses change water from a liquid, or solid, into water vapor (i.e. natural vegetation or cultivated agriculture).

Darcy's Law – French engineer Henry Darcy studied the water supply of Dijon, France and reported that the flow rate of a fluid through a porous medium is proportional to the head loss (difference between water levels at two locations) and the length of the flow path. In short, the steeper the angle of ground water flow and the longer it has to flow affects the rate at which it moves.

Empirical – A word referring to methods of gathering scientific information which are open to sensory verification: data that can be tasted, touched, smelled, or seen. Empirical studies collect information in the field as opposed to deductive (often mathematical) studies involving nothing tangible.

Evapotranspiration – Evapotranspiration (ET) refers to the amount of water "transpired by plants" and animals plus the water "evaporated" from surface waters such as ponds, rivers, or lakes. ET is usual measured in inches which is to say a crop such as alfalfa will use the equivalent of 36 inches of water poured upon a unit of ground (such as a square inch, meter, or mile) each year. Different crops have different ET values thus cool green fescue might use less (i.e. have a lower ET coefficient) water than grain sorghum but more than squash or natural vegetation. Water "consumed" from a region is often computed as the water lost to ET per unit of time.

Hydraulic Conductivity – Water moves through an aquifer when water levels are higher/lower at different locations. The term "Hydraulic Conductivity" has been developed by hydrologists to measure the ability of a volume of water to flow through the subsurface aquifer. Many things affect how much and how fast the water moves through its medium, but the terms "permeability" and "hydraulic conductivity" generally refer to the same thing. In other words, they measure how many cubic feet of water will move through a cross section of the aquifer each day. Hydraulic conductivity is usually expressed in America as gallons per day through a cross section (in square feet) of the aquifer. Many properties of an aquifer affect its permeability but among the most important is its **porosity**.

Hydrology – From the Greek word *hydro* meaning the combining form of water; a "hydrologist" is a scientist who specializes in the study of water and its properties, the term usually refers to one who studies surface water.

Hydrogeologist – A scientist who is primarily trained as both a geologist and water expert; a person who specializes in the movement and properties of subsurface water or "ground water."

<u>Model</u> – Scientists frequently develop models to help them understand complex relationships between things and this "simplified" version of reality is much like a model airplane. A model airplane is a miniature version of an actual aircraft. The technical term for how closely the model resembles what it is simplifying is known as "isomorphism." It is helpful to remember a model can be very isomorphic but still is nowhere near reality. One could construct a perfect one-tenth scale of a Boeing 747 but still could not fly it to Denver.

Models in water studies are mathematical and held within a computer, often a desktop PC. The flow model adopted in these studies was developed by the two scientists with the U.S. Geological Survey (Harbaugh and McDonald) and is widely used throughout the world. More information can be obtained about the MODFLOW model by contacting the U.S. Geological Survey at http://water.usgs.gov/public/pubs/FS/FS-121-97/ and down loading the publication "Modeling Ground-Water Flow with MODFLOW and Related Programs.

Porosity – see **storativity**

Saturated Thickness – Saturated thickness is a term used to refer to the a zone bounded on the bottom by impermeable rock and on the top by water table. The saturated thickness is that part of an aquifer where water molecules fill the porous spaces between solid materials; from the top of the water table down to the impermeable layer.

Storativity – Storativity refers to the volume of water released from storage in an aquifer per unit of surface area (i.e. a square foot of surface land) per unit change in the hydraulic head normal to that surface. Often, the terms "specific yield," "porosity," "coefficient of storage," and "storativity," have been used interchangeably to express the storage capacity of an aquifer. In its most narrow sense, specific yield measures storage in unconfined aquifers while the coefficient of storage is reserved for storage in confined aquifers. Overall, the Storativity (S) of an aquifer is expressed as the ratio of volume of water released to the volume of material drained.

Water can move through the ground because air pockets exist between the grains, the larger the pocket the greater the porosity of the subsurface material. Porosity is measured by determining the ratio of open spaces to solid material in the subsurface medium and is expressed as a percent. Porosities vary depending upon whether the material is consolidated (i.e. andesite rock) or unconsolidated (i.e. gravels/sands). While porosities can vary from 1 to 80 percent, most fall in a range between 10 percent to 30 percent. One would expect that the higher the void ratio or porosity the greater the capacity of the material to pass water but this is not always the case. Clays, for example, can have higher porosity than gravels but actually allow less water to flow. The reason for this exception is complicated but has to do with the manner in which grains align themselves as well as the water chemistry of the material and its magnetic, or "velcro."

In unconfined aquifers water is released by different geophysical mechanisms and the range of values is much lower, usually from 0.001 percent to 0.00001 percent.

Water Budget – A "water budget" is sometimes also referred to as a water "balance" or a hydrologic "budget." This is a conceptualized view of water based on the assumption the total quantity of water available to the earth is finite and indestructible. In short, it seeks to balance inflow with outflow. Generally a region is defined as a watershed and the primary input is precipitation (e.g. rain, snow, sleet) and output are surface and subsurface flows. Along the way water is intercepted by trees, grass, and other vegetation which eventually return some of the water to the atmosphere by evapotranspiration.

Watershed – A defined physical region contributing either surface or ground waters (or both) to a specified surface area drained by rivers, streams and ground waters. Watershed boundaries are defined by elevated ridges so precipitation falling anywhere within the watershed contributes to the same draining water body; in this case, the Big Wood River watershed is an 881 square mile area boundaried by the watersheds for the Boise, Salmon, and Big Lost Rivers.

Yield – The term yield, or water yield, designates the annual precipitation from a watershed less the water lost from evaporation and transpiration from plants and animals to the atmosphere (including loss from soil surface and soil moisture). Generally measured in acre feet per year.

APPENDIX 2 – CONCEPTUAL MODEL

A "conceptual" model is the starting place of all research. It is a mind's eye view of what it is you are trying to study. Once the conceptual view is specified then one seeks to construct a "numerical" which is a quantified, computer based, representation of the larger conceptual picture. The studies before us have sought to study the Wood River Valley and its water resources in general, and the groundwater aquifer beneath the Bellevue Triangle in particular.

The Wood River Valley is located entirely in Blaine County, Idaho and is the drainage corridor for the Big Wood River and its tributaries. The watershed for the river is approximately 880 square miles and defined by the ridgelines of the Pioneer, Boulder, and Smoky Mountains. The valley itself trends in a north-south direction and widens while dropping in altitude---an average of 30 feet per mile---from Galena Summit to its terminus 50 miles away where it encounters the Clay Bank, Timmerman, and Picabo Hills. The Wood River Valley is, geologically speaking, a valley formed by the down displacement of fault bounded rock, a phenomenon created by the complicated interplay of plate tectonics and erosion. Overtime, this structural depression has been filled with sediments deposited from the surrounding mountains by the erosional forces of wind and precipitation. Valley floor depositional debris is comprised of unconsolidated sediments, or alluvium, ranging in depth from 500' in the north to less than 100' in the south. In the northern end of the valley these deposits are coarse and consist of large grained gravels and sand, in the south these materials become finer and clays and silts are introduced making the soil "tighter" in certain locations.

As one travels south in the Wood River Valley both landform and geology begin to change as the narrow Upper Valley opens up to a broad plain. The southern portion of this area is called the "Bellevue Triangle," a triangular region with Hailey as the apex and legs extending to Stanton Crossing and Picabo. Underlying the triangle is a ground water aquifer much like an old porcelain bathtub, water comes in through a spout and exits down the drain: not through the sides or bottom of the tub. In the case of the valley's aquifer, the sides of the tub are subsurface extensions of the mountains and the bottom is an impermeable membrane of fused sedimentary, volcanic, and intrusive rock dating to the early Cenozoic era (65 to 25 million years ago). Since ground water has difficulty penetrating either the sides or bottom of this basin, it follows gravity in search of a drain. Precipitation and surface waters percolate down through the unconsolidated materials to join underflow coming from the Upper Valley. Scientists call the distance between the bottom impermeable liner and the top of the water table the "saturated thickness." In other words, water fills the porous "holes" in the unconsolidated spaces and the top of this unsaturated thickness is referred to as the water table. If the elevation of the aquifer is higher at one end a hydraulic gradient is created and water moves through the formation at right angles to decreasing contours. The volume and speed of ground water moving through aquifer is dependent upon many factors.

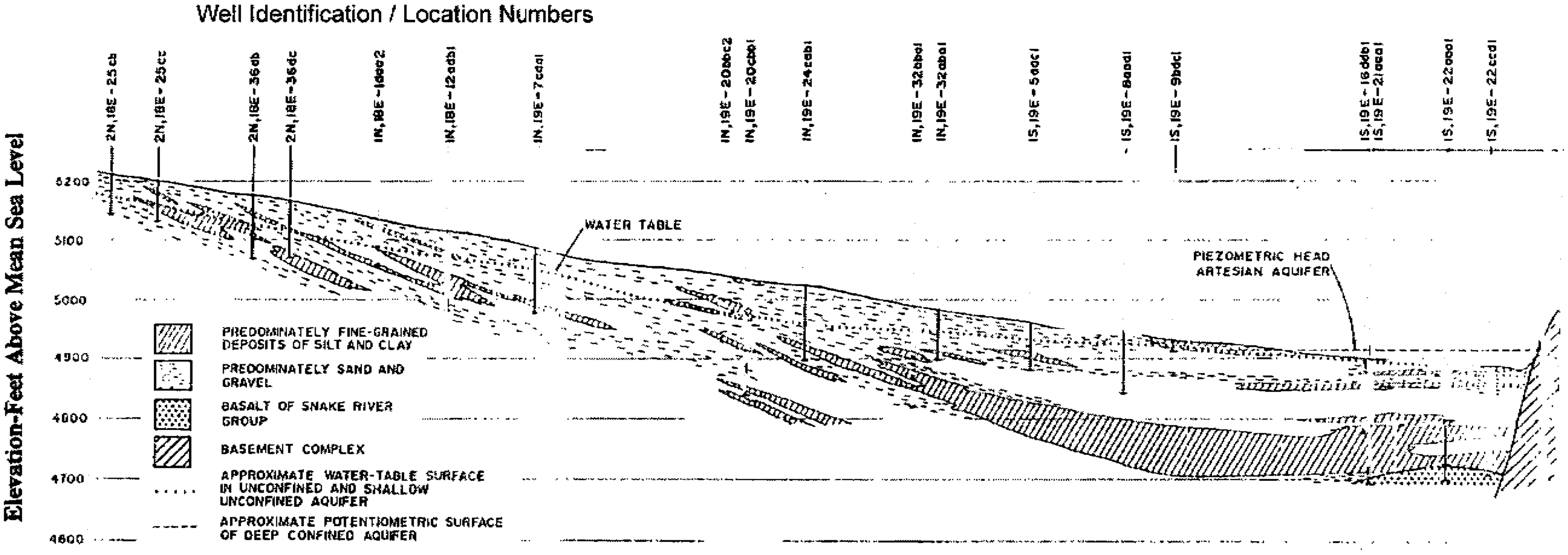
Found in the Upper Valley is a single alluvial aquifer ranging in thickness from a few feet to hundreds of feet near Hailey. No interbedded layers are believed to occur in the Upper Valley aquifer and a cross-section of 100,000 ft^2 is found at Adams Gulch which increases to 150,000 ft^2 at Gimlet; by Hailey this cross section is 820,000 ft^2. Underflow through the Upper Valley is about 10 percent of the river flow at North Fork and for any section downstream to Hailey.

Subsurface geology in the Lower Valley, however, is more complex, this is especially evident below Baseline Road due to events taking place during the Pleistocene Epoch. At that time, the Big Wood River exited southeast toward Picabo following a path similar to the roadbed of the now abandoned Union Pacific Railroad. About 2 million years ago, volcanic basalts, known as the "Snake River Group," erupted and closed the river channel forming a surface lake over the southern portion of the Bellevue Triangle. Runoff from mountain glaciers helped to fill the lake eventually spilling over and exiting to the southwest near where the Big Wood River exits today. As best as geologists can tell, this sequence occurred several times and each time a new lake was created its sediments were deposited on the new lakebed.

Alternating periods of historic lake building in the southern portion of the Bellevue Triangle contribute to an understanding of aquifer layering. North of Baseline Road, the subsurface water bearing strata is a relatively uniform "water table" aquifer, one where the medium is bounded and filled with porous materials and ground water flows in an unimpeded fashion following gravity. South of Baseline Road, however, the aquifer changes in complexity where layers, or stacked platters, begin to occur. The water table, or unconfined aquifer, rests above confined aquifers hidden below and typically varies in width from 150 feet just south of Hailey to over 300 feet at Priest Road. The second layer is called a clay "lens" and presents a non-water bearing medium, an aquitard, ranging in some locations up to 50 feet thick (see Figure A).

Below the unconfined aquifer and the clay lens are the confined or "artesian" aquifers. These porous segments transport ground water and vary in thickness from 20 feet to 50 feet. Ground water in the lower aquifers is under pressure since it is sandwiched between the bedrock below the clay lens above. Since the confined aquifer's zone of recharge occurs at higher altitude it will be pressured to rise to its recharge level. When the overlying aquitard of clay is punctured ground water is forced upwards by pressure, ground water rising to the surface in this manner is termed "artesian." Artesian waters are generally brought to the surface either by penetrating the clay lens (i.e. a well bore) or by naturally occurring faults. These deeper, confined aquifers are not found in the northern part of the Bellevue Triangle but begin to occur south of Baseline Road.
Most artesian wells are located near Highway 20 and contribute to the springs flowing westerly into the Big Wood River and easterly into Silver Creek.

A final piece of the puzzle to understand the conceptual model of the Lower Valley is to recognize the existence of its unique groundwater "divide." This line trends north to south, from Boise Baseline to the Timmerman Hills, by running parallel to, and east of, State Highway 75. Understanding the existence of this physical phenomenon helps to explain the triangle's water resources system. Curiously, while the Big Wood River surface waters flow southwesterly toward Magic Reservoir, most of the associated



FROM MORELAND (1977)

Figure A. Geologic Cross Section of Big Wood River / Silver Creek (North to South)

ground water (either from seepage or irrigation diversions) flow southeasterly towards Picabo. Understanding this unique geohydrologic phenomenon in the Lower Valley aquifer enhances our grasp of recharge mechanisms feeding the headwater springs of Silver Creek.

Water scientists believe there are six physical properties of an aquifer that best describe the hydraulic aspects of ground water. Three of these characteristics have to do with the ground water itself [density (ρ), viscosity (μ), water compressibility (β)] and the remaining three with the medium through which ground water moves [porosity (η), permeability (κ), and aquifer compressibility (α)]. All other important features of aquifers can be derived from these six properties such as storativity, transmissivity gradient or hydraulic conductance (see Glossary).

Our conceptual model of the Big Wood River/Bellevue Triangle aquifer calls for making some assumptions about physical properties of the ground water system. The ability of an aquifer to transport water is referred to as hydraulic conductivity or, as it is often called, permeability. This conductance of water can be either vertical or horizontal and is often both. Scientists estimate the horizontal conductance for alluvium, (found in the unconfined or water table aquifer) in this region to be 0.025 ft/s or 2,160 ft per day. Put in volumetric terms, some 48 cubic feet a second, or 34,800 acre feet a year of ground water move through the subsurface soils below Hailey.

Transmissivity values estimate the volume of water capable of passing through a theoretical cross section of the aquifer. Stated differently, transmissivity is a measure of the permeability of an aquifer multiplied by its thickness. Transmissivities will vary considerably within any aquifer and this is true of the Lower Valley study site. The highest transmissivities are located northwest of Gannett (300,000 ft^2/day) indicating the presence of coarse sand or gravel. South of Baseline Road, in the artesian area with confining beds, transmissivities are generally less than 30,000 ft^2 /day while West of the intersection of Baseline Road and Highway 75 (still in the artesian area), transmissivities are 70,000 ft^2/day. Near Picabo, transmissivities are highly variable and range from 7,000 to 30,000 ft^2 /day.

An aquifer's gradient is the imaginary surface of the water table as it tips and tilts in the Lower Valley from north to south. In this instance, MODFLOW projects the aquifer declines about 0.006 ft for each foot of length; this gradient can be compared to the slightly steeper surface gradient for the Big Wood River of 0.008 ft/ft.

A final attribute of the Lower Valley's aquifer deals with its ability to act as an underground reservoir. This capability is known as storativity and is generally specified as either the specific yield, for unconfined aquifers, or coefficient of storage, in confined formations. In this study, the coefficient of storage was between 0.000001 to 0.00002 percent while the specific yield was 0.05 to 0.3 or 5 to 30 percent range.

APPENDIX 3 – HYDROLOGY REFERENCE TEXTS

* Kenneth Brooks (ed.), ***Hydrology and the Management of Watersheds*** (Iowa State University Press, 1997); Ven Te Chow ***et. al., Applied Hydrology***, (New York: McGraw-Hill, 1990); Ralph G. Kazmann, ***Modern Hydrology***, (New York: Harper & Row, 1965); R. Allan Freeze & John A. Cherry, ***Ground water*** (Englewood Cliffs, NJ: Prentice-Hall: 1979); John Manning , ***Applied Principles of Hydrology*** (Englewood Cliffs, NJ: Prentice-Hall, 1996); D. K. Todd, ***Ground water Hydrology*** (New York: John Wiley & Sons, 1980); Fritiz Van der Leeden, ***The Water Encyclopedia*** (Boston: Lewis Publishers, 1990); Warren Viessman, ***et. al. Introduction to Hydrology*** 4th Edition (New York: Addison, Wesley, Longman, 1996); see also United States Department of Interior, ***Ground water Manual***, 2nd Edition (Washington, D.C.: U.S. Printing Office, 1995).

ENDNOTES

[1] Studies focussing on the hydrology of the Wood River Valley and Silver Creek watersheds include: A.L. Anderson and W.R. Wagner, "Little Wood River, Muldoon District, Blaine County" (Idaho Bureau of Mines and Geology, Pamphlet 75, 1946); Paul M. Castelin and Sherl L. Chapman, "Water Resources of the Big Wood River-Silver Creek Area, Blaine County, Idaho" (Idaho Department of Water Administration, Water Information Bulletin 28, 1972); Paul M. Castelin and J.E. Winner, "Effects of Urbanization on the Water Resources of the Sun Valley-Ketchum Area, Blaine County, Idaho, Idaho Department of Water Resources, Water Information Bulletin 40, 1975); S. H. Chapman, "Water Distribution and Hydrometric Work, Districts 7 and 11, Big and Little Wood Rivers: Shoshone, Idaho, Ann. Report Water Master, Districts 7 and 11, 1921); S. A. Frenzel, "Water Resources of the Upper Big Wood River Basin, Idaho" (U.S. Geological Survey Water Resources Investigations Report 89-4018, 1982); K.P. Grover and C. E. Brockway, "Evaluation of Urbanization and Changes in Land Use on the Water Resources of Mountain Valleys" (Idaho Water Resources Research Institute, University of Idaho, 1978); R. P. Jones, "Evaluation of Streamflow Records in Big Wood River Basin, Idaho, U.S. Geological Survey Circular 192, 1952); S. P. Luttrell and C. E. Brockway, "Impacts of Individual Onsite Sewage Disposal Facilities on Mountain Valleys, Phase 1" Research Technical Completion Report A-084-IDA Water and Energy Resources Research Institute, University of Idaho, Moscow, ID., 1982); S.P. Luttrell and C.E. Brockway, "Impacts of Individual On-Site Sewage Disposal Facilities on Mountain Valleys, Phase II – Water Quality Considerations" (Research Technical Completion Report, Idaho Water and Energy Resources Research Institute, University of Idaho, Moscow, ID., 1984); C. Y. Manuel et. al., "Effects of Nitrogenous Wastes on Aquatic Plant Growth in the Big Wood River, Idaho" (U. S. Army Corps of Engineers, Walla, Walla, WA, 1977); Joe A. Moreland "Ground water-Surface Water Relations in the Silver Creek Area, Blaine, County, Idaho" (U.S. Geological Survey, Idaho Department of Water Resources, Water Information Bulletin, NO. 45 and U.S. Geological Survey Open File Report 625, 1977); R. O. Smith "Ground water Resources of the Middle Big Wood River-Silver Creek Area, Blaine County, Idaho" U.S. Geological Survey, Water Supply Paper 1478, 1959); R.O. Smith, "Geohydrologic Evaluation of Streamflow Records in the Big Wood River Basin, Idaho" U.S. Geological Survey Water Supple Paper 1479999, 1960) and James L. Wright and Marvin E. Jensen, "1975 Evapotranspiration and Climatic Data for the Silver Creek-Bellevue Triangle, Blaine County, Idaho" (U.S. Department of Agriculture Research Service, 1976).

[2] U.S. Department of Commerce, Bureau of Census *Statistical Abstract of the United States, 1997*; see also *Ketchum/Blaine County Housing Needs Assessment*, ASI Associates (January 1997); *Blaine County Land Capacity Study*, Benchmark Associates, (January 1998) and its update (June 1999); *WrRAP Valley-Wide Buildout Study Summary*, 1997.

[3] *Op. cit.*

[4] Paul Todd and Mike Wolter, "Silver Creek Preserve Stream Quality Monitoring Summary 1991-1994" (available at The Nature Conservancy Office P.O. Box 624, Picabo, ID. 83348

[5] The Steering Committee, chaired by Paul Todd of The Nature Conservancy, was comprised of representatives from the Blaine County Commissioners, City Councils of Ketchum, Hailey, Sun Valley, and Bellevue; Water Districts 37 and 37M; Sun Valley Water & Sewer District, the Rinker Company, Ketchum Ranger District USFS, Blaine County Citizens for Smart Growth, Blaine County Ranchers Association, the Environmental Resource Center, and other individuals.

[6] C. E. Brockway and M. Akram Kahlown, *Hydrologic Evaluation of the Big Wood River and Silver Creek Watersheds: Phase I Report*, University of Idaho, Moscow, Idaho Water Resources Research Institute Kimberly Research and Extension Center, November 1994. (hereinafter ***Phase I***)

[7] *Ibid.*, pps. 2-3

[8] For a detailed discussion of data collection methods see ***Phase I***, p. 46

[9] *Research Technical Completion Report* or *Hydrologic Evaluation of the Big Wood River and Silver Creek Watersheds, **Phase II*** p. 5 (hereinafter ***Phase II***).

[10] Brennan *et. al.* estimate this region as 881 square miles in "Water Resources Data for Idaho, 1994" Volume 1. Great Basin and Snake River Basin above King Hill, U.S. Geological Survey, Water-Data Report ID-94-1.

[11] ***Phase II***, Figure 39.

[12] ***Phase II,*** Tables 23, 27.

[13] ***Phase II*** contains a discussion of **yield** approximations (pps. 113-19) and summarizes these results in Table 29. A watershed's annual yield is the amount of precipitation intercepted minus its **evapotranspiration** from vegetation and soil surface and taking an aquifer's **storativity** into account. The "Johnson" method (1982) figure for the Big Wood River watershed yield of 415,000 af/y was developed by USGS and based upon known water yields in sections of southern Idaho, while the "Hawley" (1982) technique produced 649,000 af/y using adjusted equations for western states. The "water budget" approach consists of using a mass balance of either subtracting water evaporated from precipitation or adding surface runoff with ground water underflow to determine yield and estimated 332,000 af/y. ***Phase II*** evaluated these three methods by comparing known field measurements for two smaller watersheds in the Wood River Valley with what the three methods projected. The conclusion was the Water Budget approach provides the closest approximation. This *Executive Summary* derives an estimate of

watershed yield (343,000 af/y) through the additive sum of surface and under flow exiting the Lower Valley: Big Wood River at Stanton Crossing 223,000 af (***Phase II***, Table 4); Silver Creek at Picabo 91,100 af (***Phase II***, Table 2); and underflow of Silver Creek at Picabo of 29,300 af (***Phase II***, Table 2).

[14] ***Phase I,*** Figure 15; ***Phase II,*** Figure 46.

[15] ***Phase I***, reports NOAA (Picabo) averaged 13.3 inches between 1961-1990 p. v; ***Phase II***, reports AGRIMET (Picabo) for the calibration year of 1993-94 was 10.4 inches p. 44; ***Phase II***, Table 6 for NOAA (Picabo) indicates same 13.3 inches for the period of record.

[16] ***Phase II***, pps 6 & 7, Table 14,

[17] Paul Todd, *Silver Creek Site Plan* (Ketchum, Idaho, unpublished report, 1999).

[18] ***Phase I***, p. 19; ***Phase II,*** pps. 9-13; see also "Modeling Ground-Water Flow with MODFLOW and Related Programs" U.S. Department of Interior, USGS http://waer.usgs.gov/public/pubs/FS/FS-121-97

[19] MODFLOW models 11 features: (1) flow and storage for both confined and unconfined aquifers; (2) geologic barriers faults; (3) interbedded barriers as aquitards, aquicludes; (4) flow and storage of confining lenses; (5) rivers; (6) spring discharges; (7) ephemeral streams; (8) reservoirs; (9) recharge from precipitation & irrigation; (10) evapotranspiration; and (11) well withdrawal and recharge.

[20] Appendix 1 and Freeze & Cherry, *op. cit.* P. 15 or *Les fontaines publiques de la ville de Dijon*, Paris: V. Dalmont, 1856; for Theim and Theis see glossary and Adolph Thiem *Hydrologische Methodern* 1906 and for C.V. Theis see "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground Water Storage," *Trans. Am. Geophys. Union 16, 519-524 (1935);* also Chapter 9 Bureau of Reclamation *Ground water Manual, op.cit.*

[21] ***Phase II***, pps. 123-52.

[22] see Figure 9 and Table 13 in this *Summary;* see also Note 23.

[23] ***Phase II***, pps. 107, 120.

[24] Four estimates of surface flows for these five streams are given, Water Budget (262,000 af), USGS (313,000), USGS adjusted (242,000 af) and Hawley (373,000 af). This *Summary* adopts the USGS adjusted figure of 242,000 af based on application of estimation equation to integrated watershed parameters above Hailey. See ***Phase II***, Table 29.

[25] ***Phase II***, Table 24

[26] *Population Estimates for States, Counties, Places and Minor Civil Divisions: Annual Time Series, July 1, 1990 to July 1, 1998*, U.S. Census Bureau, Internet Release Date June 30, 1999; see also *Blaine County, Idaho Land Capacity Study Update*, Blaine County Planning Division, June 1999; *Ketchum/Blaine County Housing Needs Assessment*, ASI Associates, January 1997; and *WrRAP Valley-Wide Buildout Study Summary*, 1997.

[27] The 8,800 af/y estimate used by Method 1 could actually be adjusted to 7,200 af/y. For purposes of modeling, the northern half of Hailey was counted as being in the Upper Valley and a southern half as being in the Lower Valley. Given the relatively small amount of water being discussed here this adjustment was not incorporated in Table 4 estimates.

[28] ***Phase II***, pps 122-23, Table 32.

[29] ***Phase II*** queried the Idaho Department of Water Resources permit data base to ascertain irrigated acreage for the Upper Valley. Permits do not indicate whether water is being used for primary or supplemental irrigation thus the chance of "double counting" is present. IWRRI adjusted the aggregate permitted acreage (from 10,500 acres to 6,400 acres) to offset double counting but warn this estimate could be high. In all likelihood the Snake River Basin Adjudication process will reset this figure in two years.

[30] ***Phase II***, pps. 124-125.

[31] Derived from information on pps. 125-126, ***Phase II***.

[32] Derived from information in Table 31, ***Phase II***.

[33] ***Phase II***, pps. 125-128; Table 34. These computations were made assuming 2.67 persons per residences (1,366) for rural subareas A and B and an 290 gpcd with an irrigation efficiency of 75 percent.

[34] ***Phase II***, Table 34.

[35] For a thorough discussion of IWRRI assumptions see page 128 in ***Phase II.***

[36] ***Phase II***, Table 34; note Consumptive Use changes from 13.5 inches for medium parcels and 12.7 inches for large parcels while Change in Consumptive Use remains at 7.5 inches per parcel per year.

[37] ***Phase II***, pps. 125-26. Assumptions were based on two parcel sizes of 1 acre and 0.5 acre lots. The 1 acre lots were assumed to account for 90 percent of the parcels and each parcel was configured of 8/10 irrigation and 2/10 hardscape. The remaining 10 percent of the parcels were designated as 0.5 acre lots and configured as 3/10 irrigated and 2/10 hardscape.

[38] ***Phase II*** did not make a projection to buildout but by using the estimated buildout capacity at 3,788 DU it is possible to make linear ratio projections thus if 1,366 DU diverted 4,760 af/y a linear ratio would project at 64 percent increase to 3,788 DU would divert 13,202 af/y.

[39] ***Phase II***, Table 23

[40] Computed from ***Phase I*** (Figures 13,14) and ***Phase II*** (Table 13); see also ***Phase II*** pps. 80 and 112.

[41] ***Phase I*** placed seepage below Bellevue at 22,400 af/y while ***Phase II*** increased this estimate substantially (56,800 af/y) due to an increased "zone" of seepage and difficulties in getting the model to converge with the lower value.

[42] ***Phase I***, pps. *v.*, 25,41, and 45. ***Phase I*** originally estimated diversions from the Big Wood River declined from 142,000 to 92,000 af/y between 1975 and 1993. This figure, however, also included diversions from Silver Creek as well as the Big Wood River. If diversions from Silver Creek are added to the 1993 figure then the diversions from the Big Wood River and Silver Creek in 1993 was likely in the range of 136,000 af. See ***Phase I*** Errata (January 2000).

[43] ***Phase I***, pps. iv., 22, 44.

[44] ***Phase I***, pps 20-25; ***Phase I*** Figures 5 & 6; Tables 5 & 6.

[45] ***Phase I***, p. 12

[46] Recall from the discussion of Upper Valley Municipal Water Use there are four methods of estimation; the figure used here for Hailey is based on Method 1 in Table 4.

[47] ***Phase II*** Table 27 sets total ET for natural vegetation in the 7 lower subwatersheds at 247,000 af/y by using standard ET coefficients for forest, range and brush. Within this 255 miles^2 region, however, are between 34,000 acres and 30,000 acres of crop land with higher ET coefficients that must be withdrawn from the overall estimate and substituted to derive an overall picture of consumed water. Withdrawing 87,000 af/y (the ET for 90 miles^2) and substituting known ET coefficients for typical crops then "adjusts" the ET for natural vegetation to 160,000 af/y. To this amount, however, 107,000 af/y (ET for crops substituted) must be added to produce the final estimate of 267,00 af/y for the entire Lower Valley.

[48] *Farm and Ranch Irrigation Survey*, Idaho Agriculture Statistics Service (Boise, November 1999).

[49] *Op. cit.*, Freeze & Cherry pps. 5-6.

[50] ***Phase II,*** Table 22, p. 107

[51] A computational difference exists between this *Executive Summary* and ***Phase II*** with respect to municipal consumption. This difference, of approximately 700 af, is attributable to different modes of reporting by the cities as well as counting only the southern half of Hailey for the model study site. In any event, this difference is negligible and amounts to less than 0.0001 percent of the total annual consumed water in the watershed.

[52] Tables 13 and 15 indicate an imbalance of 676 af/y. Many factors contribute to this discrepancy and given the figures provided in ***Reports*** this was the closest approximation.

[53] Estimating yields from the Upper Valley has drawn the attention of several studies. To demonstrate the variability: standard water budget method (412,000 af/y); USGS (514,000 af/y) but adjusted to local conditions (396,000 af/y); Hawley "adapted" (613,682 af/y), Frenzel (400,000 af/y); Luttrell & Brockway (369,000 af/y); and ***Phase II***'s own estimate of 396,000 af/y. This *Executive Summary* is slightly lower since it also subtracts municipal consumed water from gross precipitation. See ***Phase II***, Table 29.

[54] ***Phase I*** pps. 40-42, in particular see Figure 16

[55] ***Phase II*** contains a detailed discussion of the study site's water budget. In particular see pps. 28-34, Figures 16-19, and Table 2

[56] For discussion of MODFLOW assumptions see ***Phase II,*** pps. 87-104.

[57] The designation of this region as marshland is due mostly to anecdotal evidence, personal discussions, and some soil typologies. One personal conversation this author had with a man who had lived here since the 1950s (also a water official in the region) indicated that even as late as 1958 the area (beginning about 0.5 mile) below Baseline Road was marshy and un-cultivated. Reclamation began in the 1930s and several drains were added (i.e. Patton's drain) to reduce standing water so tillage could begin. Grover and Brockway (1978) examined aerial photography from 1943 to 1975 and concluded 4,800 newly cultivated acres were brought into production for this region while 3,800 went out of production. Of this amount, however, most of the new acres were in the reclaimed marshy zone while retired lands were from marginal zones and near the borders.

[58] ***Phase II,*** p. 91 identifies wells in sections 22, 25, and 26.

[59] For results see ***Phase II,*** Table 21, p. 104.

[60] ***Phase II,*** pps. 94-99.

[61] For a discussion of this methodology see ***Phase II*** pps. 99-103.